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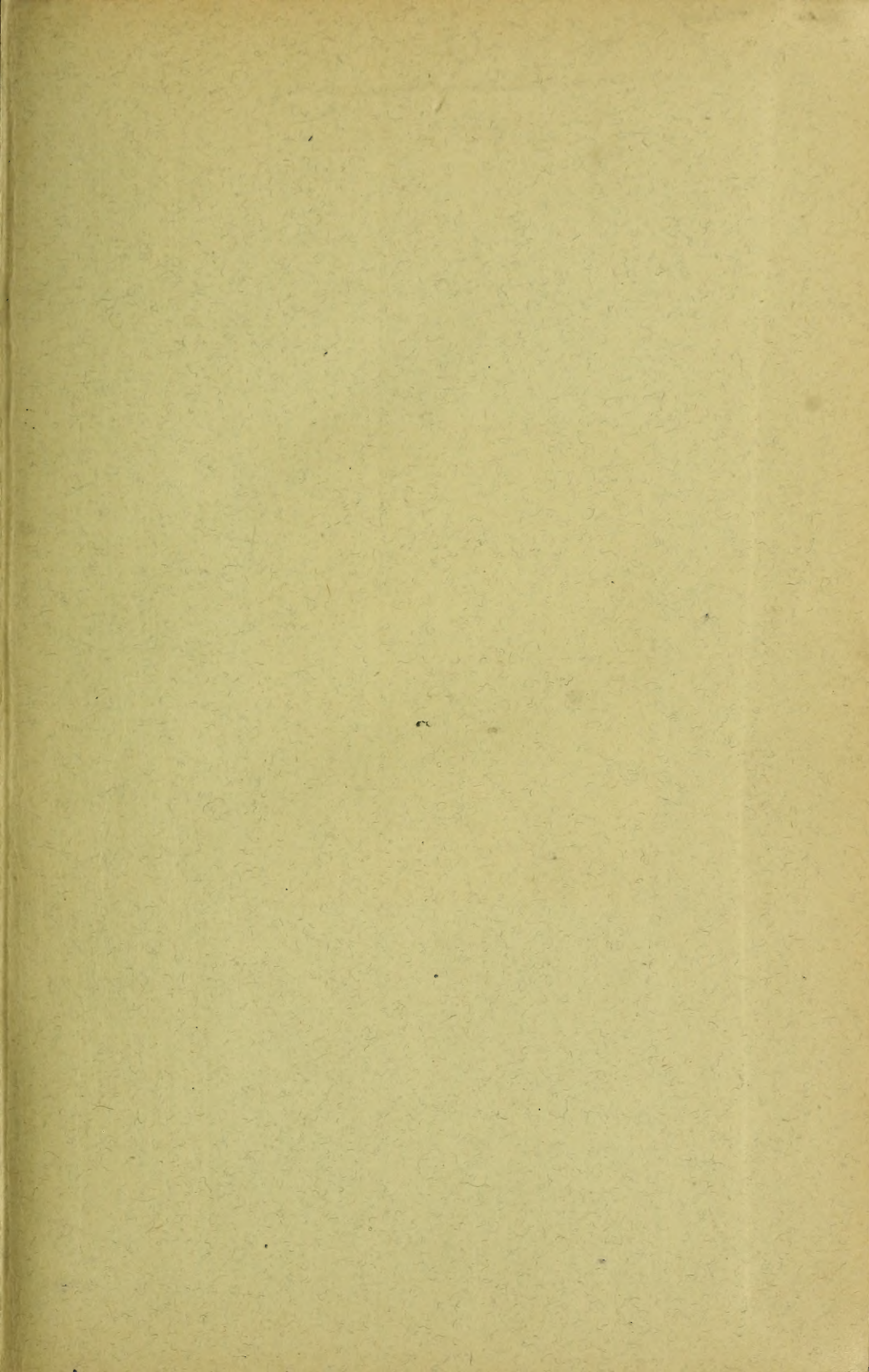
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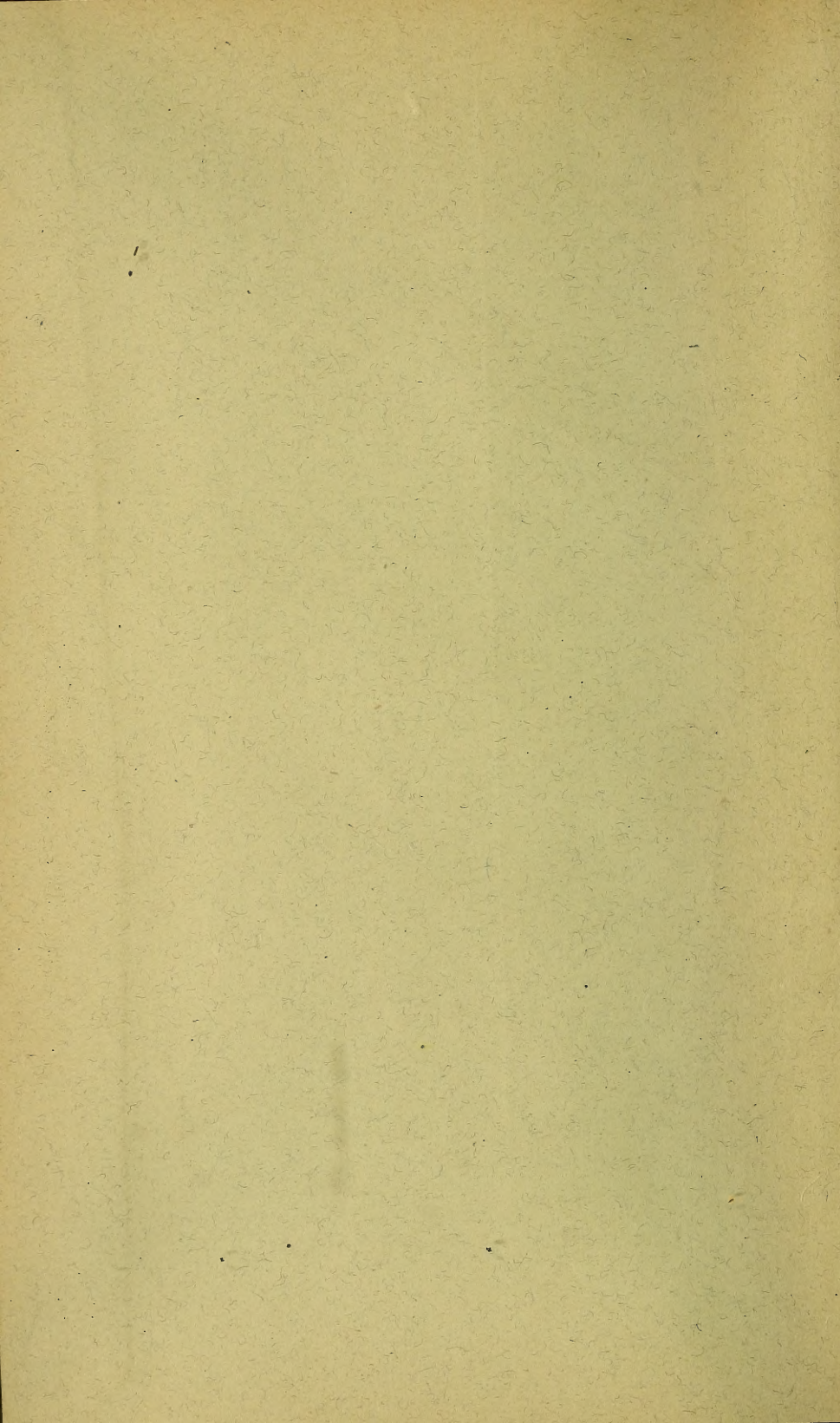
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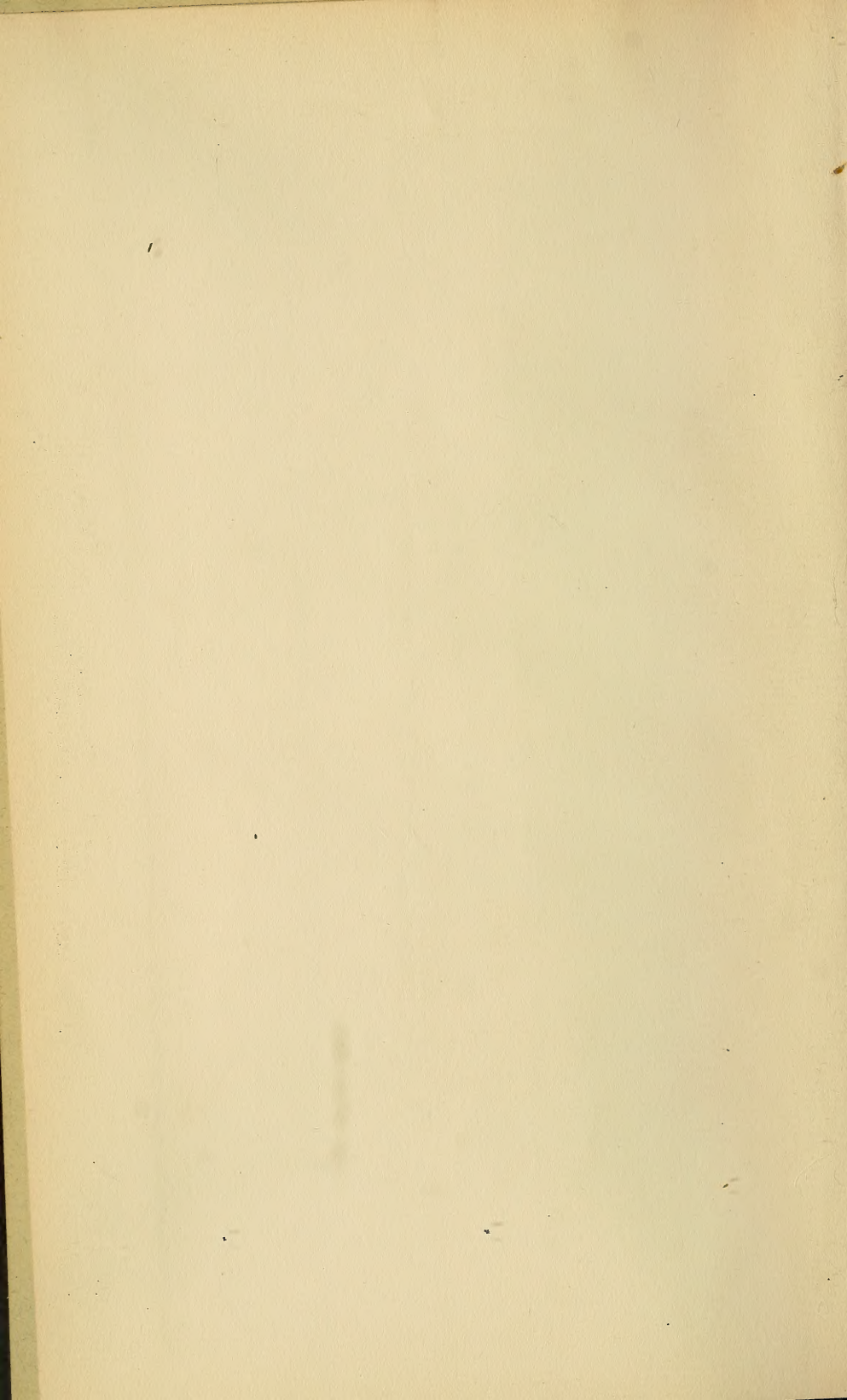
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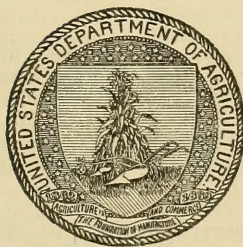
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PORTO RICAN TODY OR SAN PEDRITO (*TODUS MEXICANUS*). SLIGHTLY REDUCED.

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BIRDS OF PORTO RICO.

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INTRODUCTION.

The following report on the birds of Porto Rico is the result of investigations made by the Biological Survey in cooperation with the government of the island. Because of the damage to crops by insect pests and the resulting pecuniary loss, the Board of Commissioners of Agriculture of the island in 1911 requested the aid of the United States Department of Agriculture in an effort to determine the relations of the island birds to the insect fauna. Little was actually known concerning the economic status of many species of birds, and that little was founded chiefly upon field observation, a method not without value, but one leading frequently to error.

In Porto Rico the population is engaged primarily in agricultural pursuits, the production of sugar, tobacco, coffee, and fruits greatly overshadowing other lines of industrial activity. Under the methods of intensive agriculture now employed many insects, including the mole cricket, the cane-root-boring weevil, the May beetle, and others, are very destructive. Various methods have been employed in attempting to check the ravages of these insects, and planters are beginning to recognize that the island birds are of enormous importance in combating them. In the rural districts, however, the country people, ignorant of the services birds render, ruthlessly plunder nests and kill small birds wantonly or for food. In addition, several species of great economic importance are classed as game birds and are killed without regard to season or their value as insect destroyers.

Accurate knowledge in regard to the economic status and relative abundance of the island birds was lacking, and there was little upon which to base protective legislation. Knowledge was lacking also in regard to practicable methods for increasing useful resident species; and, finally, as to the desirability of introducing exotic insectivorous or other birds.

Investigations were begun in December, 1911, and continuous field work was carried on until September, 1912, permitting nine months of consecutive observation. All the principal regions of Porto Rico were visited, short trips were made to the adjacent islands of Vieques and Culebra, and four days were spent on Desecheo Island, in Mona Passage. As a result of this field work more than 2,200 stomachs of birds collected at all seasons were available for laboratory study and investigation, about 2,000 of which were collected by the writer and the remainder acquired from other sources. The examinations and results have additional importance as representing the first extended work of the kind carried on within the tropical regions of the Western Hemisphere.

ITINERARY.

The field work in Porto Rico covered the entire island and the more important off-lying islands, with the exception of Mona. Effort was made to visit the main agricultural areas at different seasons in order to study bird life in its relation to changing conditions of season and cultivation incident to growth. Original conditions were studied so far as possible by exploring the small areas of natural forest still remaining.

Beginning at San Juan, the capital city, on December 13, 1911, work was continued on the island until September 11, 1912, as follows (see Pl. II):

San Juan, Dec. 13-15.

Río Piedras, Dec. 16-28.

Fajardo, Dec. 29-30.

Río Piedras, Dec. 31-Jan. 4.

Caguas, Jan. 5-14.

Cayey, Jan. 15-25.

Aibonito, Jan. 26-Feb. 4.

Aibonito to Río Piedras, Feb. 5.

San Juan, Feb. 6-8.

Mameyes, Feb. 9-Mar. 1.

Hacienda Catalina, Mar. 2-12.

Mameyes, Mar. 13-14.

San Juan, Mar. 15.

Vieques Island, Mar. 16-Apr. 4.

Culebra Island, Apr. 5-22.

Louis Peña, or Southwest Cay, Apr. 11.

Culebrita Island, Apr. 15.

Vieques Island, Apr. 23.

Naguabo, Apr. 24.

San Juan, Apr. 25.

Salinas, Apr. 26-May 2.

Yabucoa, May 3-11.

Patillas, May 12-14.

Ponce, May 15.

Yauco, May 16-28.

Maricao, May 29-June 5.

Mayagüez, June 6.

Añasco, June 7-8.

Aguadilla, June 9-12.

Desecheo Island, June 13-16.

Aguadilla, June 17.

Lares, June 18-July 1.

Quebradillas, July 2-6.

Manatí, July 7-11.

Ciales, July 12-18.

Bayamón, July 19-25.

Comerio, July 26-31.

Bayamón, Aug. 1.

Toa Alta, Aug. 2.

Utua, Aug. 3-9.

Adjuntas, Aug. 10-16.

Juana Díaz, Aug. 17-22.

Ponce, Aug. 23.

Cabo Rojo, Aug. 24-31.

Cabo Rojo to Caguas, Sept. 1-2.

Humacao, Sept. 3-9.

San Juan, Sept. 10-11.

PHYSIOGRAPHY OF PORTO RICO.

Approximately 100 miles long by 40 broad, Porto Rico, though the smallest of the Greater Antilles, possesses considerable diversity of surface. From Mayagüez to Humacao extends a mountain chain known in the west as the Cordillera Central and east of Aibonito as the Sierra de Cayey. Northeast of the latter runs the Sierra de Luquillo, rising in El Yunque to 3,406 feet above sea level, the highest point on the island. From this central divide the descent to the coast is abrupt and much broken by series of hills cut by deep ravines. As the range is nearer the south coast the larger streams flow to the north. A low divide separates the northeastern mountain mass from the main range, and others, higher, offer passage across the island at several points.

The coastal region is formed by a narrow plain extending around the island, though in a few places the hills approach the sea abruptly. In this plain, conical limestone hills rising to sharp points are frequent, and inland is found a rough limestone foothill region. Mangrove swamps and shallow lagoons, many of which have been drained of late years, are found near the mouths of rivers on the north and west coasts, and at Guánica is a considerable body of fresh water with surrounding marshes.

Governed by the prevailing northeast trade winds, rainfall varies greatly in different localities. For the entire island the annual average precipitation amounts to 77.3 inches. The south coast is relatively dry, the greatest precipitation occurring on the north side. The maximum volume of rain falls in the northeast on El Yunque and about its base, where the annual average is 135 (maximum 169) inches. The northern slopes of the central mountain range as a whole secure the greatest quantity. Along the northwest coast from Isabela to Camuy is an area of small precipitation, at times very dry, while the south coast from Cabo Rojo to Guayama is almost universally so, the annual average being 40 inches or less. The rainy and dry seasons are not well defined, rains occurring throughout the year. The minimum rainfall is in February, while the maximum occurs from May to November, varying with the locality.

Vieques and Culebra Islands are comparatively low, with many rounded hills. Lagoons are found near the sea, though they are frequently dry. The general appearance of the islands is that of the south coast of Porto Rico. Desecheo Island in Mona Passage is smaller, and rises in two conical hills from the sea to an altitude of about 400 feet. A rough path leads up and down over the rocks above the beach, but inland the brush is almost impassable. Mona Island, as described by Bowdish (MS.), is 7 miles long by 3 or 4 wide and is rather barren. It slopes gradually from the higher north

end to the south and, though elevated, is comparatively level. Caves are numerous in the face of the cliffs above the sea. At the southwest is a comparatively low strip of ground. Both Mona and Desecheo are dry and arid.

BIRD LIFE.

As compared with corresponding latitudes in Central America and Mexico, the avifauna of the Greater Antilles is very poor in the number of species, as is usual in island groups distant from continental regions. Porto Rico, smallest of the chain to which it belongs, is also least in number of forms of bird life, a fact explained by its comparative isolation and remoteness from evolutionary centers in the large land areas. Thus far 162 species and subspecies are recorded for the region, including Porto Rico, Mona, Desecheo, and the American possessions in the Virgin Group, while 16 others are included as hypothetical. A number of forms recorded by Ledru (1810) are disregarded as wholly improbable. Of the bona fide forms, 94 breed on the islands, 63 are visitants during migration, and 5 species, perhaps residents at one time, may be called accidental. Among the resident species 25 are peculiar to the region under discussion (24 on Porto Rico and 1 on Mona Island) and 3, though breeding there, are absent during part of the winter season. Six have been introduced from foreign countries and are now feral or have been within recent years.

Birds are generally more abundant on the coastal plain than inland, the swamp-loving species and water birds being confined chiefly to the neighborhood of the sea. The range of a number of Greater Antillean birds finds its most eastern extension in Porto Rico, and a few forms come up through the Lesser Antilles to Vieques Island, but go no farther. Mona and Desecheo, isolated peaks on the ocean floor, are populated almost entirely by sea birds, few land birds occurring there.

On the average, about 30 species are found in reasonable numbers during summer in almost any inland locality on Porto Rico, and a few more North American migrants are added in winter. Near the coast these numbers are augmented somewhat by water birds. The species are few, but individuals, especially of dominant forms, are plentiful, though often overlooked by a casual observer because of their retiring habits and secretiveness. Certain areas are seemingly destitute of bird life, but to show that birds are more numerous in Porto Rico than is commonly supposed, two censuses were taken during the breeding season, in which accurate count was made of the number of species and individuals of each seen. On May 24, at Yauco, 391 birds belonging to 35 species were listed in four hours in traversing a distance of 5 miles through cane fields, open and

brush-filled pastures, and areas given over to small crops. Twenty-six of these species, comprising 252 individuals, belonged to beneficial forms of economic importance, and the remainder, 139 individuals of 9 species, were neutral forms, harmless, and inoffensive. Near Lares, in the interior, a census taken on June 28 covered an area of approximately the same size, but one of coffee plantations and small farms. Here 335 individuals of 27 species were seen; of these, 21 species (300 individuals) were beneficial and 6 species (35 individuals) were neutral. These results compare very favorably with censuses taken on similar cultivated areas in eastern United States during the breeding season. The relative importance of birds to the major agricultural interests of the island may best be understood by a consideration of species commonly found in cane fields, coffee plantations, and citrus groves.

BIRDS FOUND IN CANE FIELDS.

Cane fields cover the larger part of the arable lowlands of the island and in favorable localities extend over the foothills and higher slopes. As these fields are cultivated intensively and offer no safe nesting sites unless bordered by palms or other trees, they are used only as feeding grounds by birds coming in from near by where cover and security are to be found. The fields are frequented chiefly when being plowed or cultivated, as grubs, mole crickets, and other insects are then readily accessible to the birds. When the cane grows higher, birds are seen in the roads, which cut the fields into squares, and in the dense tangle of stalks some species find convenient shelter. No bird harms the cane in any way, and those that are not directly beneficial by destroying insects, and to a less extent weed seeds, are neutral and do no damage. During most of the year, only adult insects of the important pests are available, immature forms being exposed mainly at plowing time. To see a flock of blackbirds at that season following closely in the furrows behind the plow, eating greedily and carrying food to their young, emphasizes their value. Following is a list of birds found regularly in the cane fields; a number that occur more or less casually are not included:

Martinete (<i>Butorides v. cubanus</i>).	Golondrina (<i>Progne dominicensis</i>).
Garza (<i>Florida c. cærulescens</i>).	Ruiseñor (<i>Mimus p. orpheus</i>).
Falcón (<i>Falco s. loquacula</i>).	Pizpita dorada (<i>Seiurus aurocapillus</i>).
Rolita (<i>Chæmepelia p. trochila</i>).	Reinita (<i>Cæreba portoricensis</i>).
Tórtola (<i>Zenaida z. lucida</i>).	Veterano (<i>Amandava melpoda</i>).
Judío (<i>Crotophaga ani</i>).	Mariquita (<i>Agelaius xanthomus</i>).
Zumbador (<i>Anthracothorax aurulentus</i>).	Mozambique (<i>Holoquiscalus brachypterus</i>).
Pitirre (<i>Tyrannus d. dominicensis</i>).	Chamorro bicolor (<i>Tiaris b. omissa</i>).
Golondrina (<i>Petrochelidon f. paciloma</i>).	Gorrión (<i>Tiaris o. bryanti</i>).

The same species frequent tobacco fields and areas of small farms, where legumes, maize, and other small crops are grown.

The smaller shorebirds are often found in migration in low wet fields, and other birds frequently venture into the borders of the crop before it is cut.

BIRDS FOUND IN COFFEE PLANTATIONS.

The extensive forests which formerly covered Porto Rico have been replaced in the interior to a great extent by coffee plantations; only small sections of second growth are left, and these diminish steadily year by year. The most extensive region devoted to coffee culture is in the western end of the island around Maricao and Adjuntas, but large fincas occur through the hills of the entire island and in a few places on level ground near the coast. The low coffee trees and attendant shade trees covering them do not seem to supply all the needs of the original forest-dwelling species, though many have adapted themselves readily to the changed conditions. Parrots, crows, and courlans have almost disappeared, and other species, greatly reduced in numbers, are restricted in their range to the dense forest growths remaining on inaccessible hills or on land of little value.

In the coffee plantations changing seasons offer little variation, except in the flowering and the gradual maturing of the coffee berries. Once, or perhaps twice, in the year the ground is cleared somewhat and the trees trimmed, and later, pickers come through gathering the crop; but during most of the year, except near the paths leading through the fincas, there is little human interference with the wild life found there. Insects, many of them injurious, are common, and make many a meal for the birds which harbor in the plantations; while berries, seeds, and wild fruits in their season offer a superabundant supply to the birds which prefer vegetable food. It is claimed that birds do some damage to ripening coffee berries by eating the sweet pulp surrounding the inner berry, but as yet this charge is unsubstantiated. The damage is done apparently by rats, which, being unseen, are not suspected, the birds getting the credit for the misdeeds of the rodents. Many species of birds, as woodpeckers, flycatchers, cuckoos, and others, are of great benefit here, and only rarely can any of the forms found in the coffee district be called injurious. In the absence of forests, these plantations serve as centers of distribution for birds, and so aid in keeping at a maximum the number of individuals in each section, for from their shelters the birds spread into the more open hedgerows and scattered tree growths of the surrounding country. The following list enumerates the more common of the avian residents of coffee plantations, and includes several northern forms that winter here in numbers sufficient to render them of economic importance:

Falcón (*Falco s. loquacula*).
 Perdiz (*Geotrygon montana*).
 Paloma turca (*Columba squamosa*).
 Pajaro bobo (*Coccyzus m. nesiotes*).
 Pajaro bobo mayor (*Saurothera vicilloti*).
 Carpintero (*Melanerpes portoricensis*).
 San Pedrito (*Todus mexicanus*).
 Múcaro (*Gymnasio n. nudipes*).
 Zumbadorcito (*Ohlorostilbon maugæi*).
 Zumbador verde (*Anthracothonax viridis*).
 Clérigo (*Tolmarchus taylori*).
 Juf (*Myiarchus antillarum*).
 Bobito (*Blacicus blancoi*).
 Golondrina (*Petrochelidon f. pæciloma*).
 Zorzal (*Mimocichla a. portoricensis*).
 Julian chiví (*Vireo latimeri*).

Bien-te-veo (*Vireosylva c. calidris*).
 Candelita (*Scotophaga ruticilla*).
 Bijirita adalaida (*Dendroica adelaidæ*).
 Bijirita aplomada (*Dendroica c. cerulea*).
 Pecho de oro (*Compsothlypis a. usneæ*).
 Bijirita trepadora (*Mniotilta varia*).
 Reinita (*Cæreba portoricensis*).
 Calandra (*Icterus portoricensis*).
 Verdoso (*Nesospingus speculiferus*) (of local distribution).
 Reina mora (*Spindalis portoricensis*).
 Jilguero (*Tanagra sclateri*).
 Gallito (*Loxigilla portoricensis*).
 Chamorro bicolor (*Tiaris b. omissa*).

BIRDS FREQUENTING CITRUS GROVES.

The citrus groves of Porto Rico are growing steadily in extent, and it is of vital interest to the growers that birds accept the new conditions brought about and make the orchards regular feeding grounds. Rumors that a bird injured the fruit by puncturing it could not be substantiated. A few birds, as the oriole and spindalis, were seen eating oranges, but in every case they attacked only wild fruit that was dead ripe and beginning to soften. The honey creeper, too, came to sip the juice when the oranges were once broken open. Quail-doves pecked open the rotting sweet oranges for the seeds as they lay on the ground, but no birds were found attacking sound fruit in the groves. Insectivorous species in feeding about the trees destroy innumerable pests and assist in keeping the trees clean. The open spaces and shady perches found are attractive to a number of birds, and when nests are built in the orchards care should be taken not to disturb them. Many birds now finding shelter in brushy areas surrounding the groves resort to the orchards to feed during the day. The following list of birds observed mainly in the Bayamón district and about Río Piedras includes some of the most beneficial species on the island:

Falcón (*Falco s. loquacula*).
 Playero (*Oxyechus v. rubidus*).
 Rolita (*Chamepepla p. trochila*).
 Tórtola (*Zenaida z. lucida*).
 Judío (*Crotophaga ani*).
 Zumbador (*Anthracothonax aurentus*).
 Pitirre (*Tyrannus d. dominicensis*).
 Clérigo (*Tolmarchus taylori*).
 Juf (*Myiarchus antillarum*).
 Golondrina (*Petrochelidon f. pæciloma*).
 Ruiseñor (*Mimus p. orpheus*).
 Julian chiví (*Vireo latimeri*).
 Bien-te-veo (*Vireosylva c. calidris*).

Bijirita galana (*Dendroica discolor*).
 Bijirita adalaida (*Dendroica adelaidæ*).
 Pecho de oro (*Compsothlypis a. usneæ*).
 Bijirita trepadora (*Mniotilta varia*).
 Reinita (*Cæreba portoricensis*).
 Diablito (*Spermestes cucullata*).
 Mariquita (*Agelaius xanthomus*).
 Calandra (*Icterus portoricensis*).
 Mozambique (*Holotrisacus brachypterus*).
 Reina mora (*Spindalis portoricensis*).
 Chamorro bicolor (*Tiaris b. omissa*).
 Gorrión (*Tiaris o. bryanti*).

ECONOMIC CONSIDERATIONS.

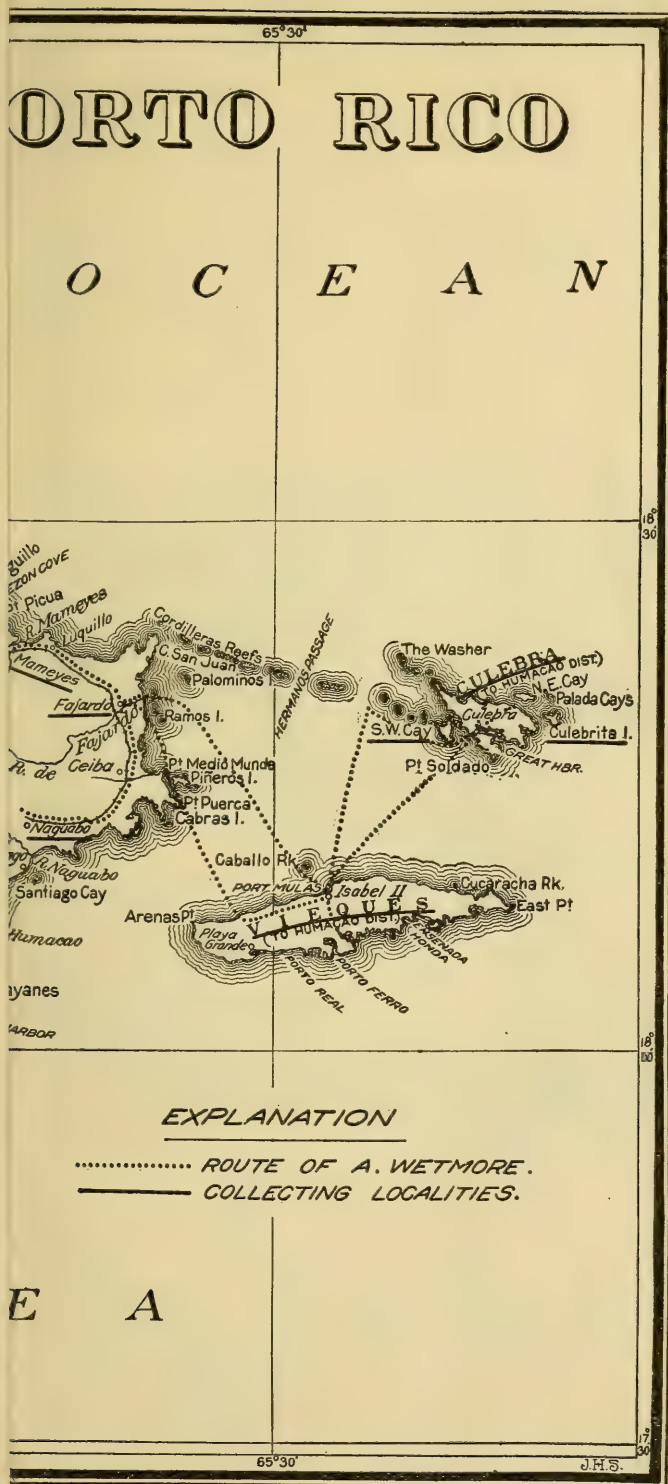
The food of the birds considered in this report does not exhibit the seasonal variation so noticeable in the case of birds of more northern

latitudes. The food of resident birds in the United States shows in many instances a predominance of insects in the warmer season and of vegetable matter in the winter months, though many specialized forms may feed on one or the other throughout the year. In Porto Rico, because of the even temperature and slight climatic changes, birds are not forced to vary their diet; consequently the percentages of animal and vegetable food are relatively stable from month to month, and a bird is vegetarian or predacious, or both, throughout the year, according to its natural bent. Young birds of partially insectivorous species, when abandoned by their parents and left to their own resources, often feed largely upon berries and other vegetable matter, but as they become more adept secure the same kind of food as their parents.

Among resident forms, birds belonging to families which in temperate latitudes feed almost entirely on insects, eat great quantities of vegetable matter. This is especially noticeable among flycatchers. Of the five forms inhabiting these islands only one, the bobito (*Blacicus blancoi*), is truly insectivorous; the others, all birds of fair size, consume many more berries and wild fruits than do their representative forms in the north; and one, the elainea (*Elainea m. martinica*), is almost entirely vegetarian. Small wild fruits and berries abound at all seasons, offering an easily obtainable food supply. Some North American migrants, predacious in their northern homes, here follow the example of native forms and feast on the bountiful crop of berries before them.

In Porto Rico, birds which feed on wild fruits almost entirely, as the spindalis, are not at all injurious. The coffee berry, with its sweet outer covering, is the only important small cultivated fruit, and from the evidence available it is left untouched by birds, though two species are locally believed to eat it. The distribution of seeds of wild fruits can not be charged against the birds, as none of the plants or shrubs disseminated are of importance as noxious species. Small grains are grown in comparatively small areas and are little eaten by birds. The few kernels of corn taken by blackbirds amount to nothing, and none of the seed-eating pigeons examined had taken grain.

Among the common birds found in Porto Rico none, fortunately, may be called wholly pernicious. The small bird-eating *Accipiter* found at Maricao is certainly injurious, and its larger relative, the red-tailed hawk, is troublesome when it acquires a taste for poultry; but some species, while to a certain extent destructive, make up for their damage in other ways. Several birds eat large numbers of lizards and tree toads, seemingly without reducing their numbers, as these creatures are to all appearances as abundant as is possible.





Only one lizard, the siguana (*Ameiva exul*), an important terrestrial form, is disappearing. Few of these, however, are eaten by birds, so that their diminution is to be charged to other agencies, perhaps to the mongoose, as this lizard can not climb. Many spiders also are eaten, more especially in the dry localities where they abound.

The value of the birds studied here is necessarily ascertained largely through a consideration of their insect food, certain dominant insect forms being so destructive that their bird enemies are of the utmost importance. The economic status of many insects common in Porto Rico is at present uncertain, and as they are more thoroughly studied some will undoubtedly prove very destructive; the lists of insects identified, as contained in the body of this report, will then serve as an index to their bird enemies so far as at present known. It is unfortunate that a robust bird like the pearly-eyed thrasher (*Margarops f. fuscatus*) should devote its attention to wild fruits instead of to insects, but the conditions favor frugivorous species.

With these brief general statements, we pass to a consideration of the bird enemies of a few of the well-known insect pests.

BIRD ENEMIES OF THE MOLE CRICKET.

The changa, or mole cricket (*Scapteriscus didactylus*), is without doubt the best-known insect in Porto Rico, as it is among the most injurious. Though found in other parts of the West Indies, in South America, and in southern United States, its ravages reach their maximum in the region under consideration. Living almost entirely in the ground, it escapes attention for the most part, and the adult, with its strong fossorial front legs and chitinous thorax, is too large and tough a morsel for many birds. The nymphs, small images of their parents, and varying in size with age, are more attractive to the average bird. At plowing time many are exposed to the watchful eyes of their enemies, and others, forced near the surface in the lowlands by water in the soil, are unceremoniously haled forth and swallowed. The blackbird (*Holquiscalus brachypterus*), popularly considered one of the greatest enemies of "la changa," in reality destroys but few, though it sustains its reputation as a beneficial species in other ways, as will presently be seen. Other species, however, make up for the blackbird's shortcomings, and among them the despised martinete (*Butorides v. cubanus*), ridiculed for its ungainliness, ranks foremost. Standing watchfully, with head drawn in, among the short growth of the young cane fields, or walking with lengthened stride along the border of lowland pools, it spies and avidly swallows both adults and young of the mole cricket. The species at present known to aid in suppressing this pest number 21.

and following is a list of them arranged somewhat in order of importance (figures following the name of each species indicate the percentage formed by the mole cricket in the total bulk of the food) :

	Per cent.		Per cent.
Martinete (<i>Butorides v. cubanus</i>)	54.33	Zorzal (<i>Mimocichla a. portoricensis</i>)	0.86
Falcón (<i>Falco s. loquacula</i>)	28.69	Múcaro (<i>Gymnasio n. nudipes</i>)	.60
Playero (<i>Oxyechus v. rubidus</i>)	14.42	Canario de manglar (<i>Dendroica p. bartholemica</i>)	.25
Putilla (<i>Actitis macularia</i>)	10.78	Gorrión (<i>Coturniculus s. intricatus</i>)	.25
Garza (<i>Florida c. cærulescens</i>)	7.23	Mozambique (<i>Holoquiscalus brachypterus</i>)	.21
Judío (<i>Crotophaga ani</i>)	5.69	Calandra (<i>Icterus portoricensis</i>)	.21
Ruiseñor (<i>Mimus p. orpheus</i>)	3.62	Pajaro bobo (<i>Coccyzus m. nesiotetes</i>)	.21
Clérigo (<i>Tolmarchus taylora</i>)	3.04	Zorzal negro (<i>Margarops f. fuscatus</i>)	.16
Pitirre (<i>Tyrannus d. dominicensis</i>)	2.36	Becacina (<i>Gallinago delicata</i>), one bird only examined.	
Juf (<i>Myiarchus antillarum</i>)	1.27		
Garzon blanco (<i>Herodias egretta</i>)	1.00		
Julian chiví (<i>Vireo latimeri</i>)	.90		

BIRD ENEMIES OF THE SUGAR-CANE ROOT-BORER.

The sugar-cane root-borer (*Diaprepes spengleri*), known also as the orange leaf-weevil, is abundant and has long been known as injurious to citrus stock. The adult feeds on leaves of the sugar cane, orange, guava, avocado, mango, rose, and jobo, while recently the grub has been found to be the destructive cane root-borer whose depredations have been known for some time. The adult is common everywhere in weeds, cane fields, and on trees; and though two broods are said to emerge, a few may be found throughout the year. The grub, buried in the ground, is exposed to the attacks of birds during plowing and cultivation only. None were identified in any of the stomachs examined, though adults were eaten commonly by a number of birds. The blackbird especially eats large numbers, and the remains of as many as 16 were found in a single stomach. The larger flycatchers captured the greatest quantities, and the querulous-voiced ani is not far below them in usefulness. The insect was identified in the stomachs of 17 species of birds, listed in the order of their importance as follows:

	Per cent.		
Clérigo (<i>Tolmarchus taylora</i>)	18.47	Calandra (<i>Icterus portoricensis</i>), in 3 stomachs.	
Pitirre (<i>Tyrannus d. dominicensis</i>)	17.19	Gallito (<i>Loxigilla portoricensis</i>), in 3 stomachs.	
Juf (<i>Myiarchus antillarum</i>)	11.22	Gorrión (<i>Coturniculus s. intricatus</i>), in 1 stomach.	
Mozambique (<i>Holoquiscalus brachypterus</i>)	9.69	Zorzal negro (<i>Margarops f. fuscatus</i>), in 1 stomach.	
Judío (<i>Crotophaga ani</i>)	7.09	Pajaro bobo (<i>Coccyzus m. nesiotetes</i>), in 1 stomach.	
Múcaro (<i>Gymnasio n. nudipes</i>)	1.80	Pajaro bobo (<i>Coccyzus americanus</i>), in 1 stomach.	
Mariquita (<i>Agelaius aanthomus</i>)	1.72	Gallareta (<i>Gallinula g. galeata</i>), in 1 stomach.	
Bien-te-veo (<i>Vireosylva c. calidris</i>)	.51		
Ruiseñor (<i>Mimus p. orpheus</i>)	.25		
Zorzal (<i>Mimocichla a. portoricensis</i>), in 1 stomach.			

BIRD ENEMIES OF THE WEEVIL STALK-BORER.

The weevil stalk-borer (*Metamasius hemipterus*) is more common than generally supposed, as numbers were found in the stomachs

of certain species of birds examined. The larva bores in the stalks of the sugar cane, and the adult insect, a long-snouted weevil, hides at the bases of the leaves. It is not at present known to injure other crops. The adult alone is available as food for birds. Fragments of these beetles were found in the following:

	Per cent.	
Mozambique (<i>Holoquiscalus brachyp- terus</i>)	5.44	Judío (<i>Crotophaga ani</i>), in 1 stomach.
Pitirre (<i>Tyrannus d. dominicensis</i>)	5.30	Mariquita (<i>Agelaius xanthomus</i>), in 1 stomach.
Clérigo (<i>Tolmarchus taylori</i>)	1.53	Calandra (<i>Icterus portoricensis</i>), in 1 stomach.

BIRD ENEMIES OF THE MAY BEETLE.

Locally doing great damage, the May beetle, or caculo (*Lachno-
sterna* sp.), may be briefly mentioned as another well-known economic species. In the immature stage as the "white grub," or gusano blanco, thousands are turned out in furrows during the plowing season and then are exposed to the attacks of birds. The adults are strictly nocturnal, and so escape many birds, and the grubs are exposed for only a short time. However, several birds had eaten either grubs or beetles and are listed here. Of these, the múcaro (*Gymnasio
n. nudipes*) is by far the most important, and by its nocturnal habit can successfully cope with adults when they are flying.

	Per cent.	
Múcaro (<i>Gymnasio n. nudipes</i>)	24.40	Pitirre (<i>Tyrannus d. dominicensis</i>), in 1 stomach.
Mozambique (<i>Holoquiscalus brachyp- terus</i>)	1.61	Capacho (<i>Antrostomus carolinensis</i>), in 1 stomach.
Garza (<i>Florida c. cærulescens</i>)	1.00	
Pajaro bobo (<i>Coccyzus m. nesiotus</i>)	.05	

METHODS OF INCREASING BIRDS.

Though, as has been stated, birds are more common in Porto Rico than is locally believed, it is desirable that their numbers be increased that they may aid in keeping injurious insects in check. One of the first steps in an attempt to increase bird life is to provide adequate legal protection both for the birds and for their nests and to make sure that the laws are properly enforced. Game laws should restrict the hunting of game birds to certain open seasons, as outlined in the report which follows; should provide bag limits; and also allow the collection of specimens under permit for scientific study and research. Although it may seem that birds should be protected absolutely, the few used in a proper study of their habits and economic status would have no effect on the great mass of individuals of any given species. Without such scientific study no advance can be made in knowledge regarding the birds themselves.

As an aid in the enforcement of protective laws no method is of more value than the education of school children. If they are taught to look on birds as friends and not to disturb them, many a brood of

young that otherwise would be destroyed will reach maturity. Courses in nature study have been found interesting and profitable wherever undertaken in elementary schools, and will prove especially so in Porto Rico. The detailed knowledge of the natives concerning their island flora and fauna was noted by early historians, and has been corroborated and enlarged upon by travelers in the island for many years. Every bird, tree, and shrub was recognized and had its name, sometimes that bestowed by the aborigines, sometimes a cognomen given by the Spaniards from some resemblance to a form with which they were familiar in their native land. Now that a considerable proportion of the population is concentrated in towns, much of this stock of common knowledge is being lost, and many of the younger generation are strangers to it. The country boys and girls traveling to and from school through the coffee plantations or along the roads and trails become versed in the lore of out-of-doors from their elders, but in towns lack of this information among children is noticeable. Names remain without proper association with the objects to which they pertain, and a fund of common knowledge ages old in its inception and growth is in danger of being lost. It seems natural for a boy to throw stones or break eggs in the nests which his sharp eyes discover, but under proper guidance these misapplied energies may easily be directed to the encouragement and preservation of his feathered friends.

That birds need shelter as well as protection will not be questioned, and owners of plantations should look carefully to providing this if it is not already present. A long level stretch of cane or tobacco, with not a tree or other obstruction to break its continuity, while a pleasing sight to the agriculturist, offers little encouragement to the bird in search of shelter and food. A similar stretch of cultivated land, with lines of symmetrical royal palms or coconuts along the roadways and dense clumps of graceful bamboos adorning the borders of streams, while not losing an iota of its productiveness, will gain in esthetic charm and beauty and provide an attractive feeding ground for birds which will more than repay the owner in the great numbers of injurious insects they consume.

In cane fields during the preparation of the soil fence posts offer convenient perches for such birds as the sparrow hawk and gray kingbird, which require commanding outlooks from which to watch for their prey. Later these posts are overshadowed by the cane, but if more trees were present inducement would be offered the birds to frequent the fields throughout the season. The jobo (*Spondias lutea*), with its open limbs and small shade, is a favorite perch and nesting site of birds, and the spiny trunk is a protection against terrestrial nest robbers.

All birds desire shelter from the burning heat of the midday sun, and this should be made available. Green herons, or martinets, and anis prefer clumps of bamboos, while blackbirds frequent palms. Brushy growths on waste lands should not be cleared too closely, as they harbor many useful birds, while in localities where birds are scarce small plantings might be made on the least valuable soil for their encouragement. Tobacco fields seem especially barren of shelter, and though for a small portion of the year the more valuable parts are shaded with cheese cloth, during the remainder birds would perform valuable service in ridding the soil of insects.

Another class of birds needs safeguarding in a different way. In the coast region at present are found numbers of little blue herons, snowy herons, and green herons, which nest in colonies in dense growths of tall mangroves. From these rookeries they spread inland into the cultivated areas in search of food, destroying large numbers of mole crickets and other injurious insects. These swampy tracts are being steadily cut over and cleared in the quest for wood for charcoal, and thus breeding places are destroyed. The little green heron, or martinete, can survive this, as it nests frequently in bamboos and other trees, but the other species will be greatly reduced in numbers unless some of these shelters are preserved. Part of this swampy territory is still under government control and could be set aside as bird reserves and the important rookeries preserved; but where these are found on private land the owners should be far-sighted enough to leave untouched portions of the swamps occupied by the herons, as such measures will repay them in the long run. The most important localities where conditions should be investigated are between Salinas and Guayama, below Yabucoa, Piñero Island off Ceiba, Comezon Cove north of Mameyes, the lagoons north of Río Piedras, the region about San Juan Bay, the coast region near Vega Baja, and the swampy regions about Porto Real and Joyuda near Cabo Rojo. Suitable localities, even though at present cleared, would in a very few years be covered by new growth and so furnish shelter.

The martin, which nests in natural cavities in trees or in crevices about buildings in towns, might be attracted to the country if nesting boxes were provided. A hollowed-out calabash on a pole would be as readily accepted as a more pretentious mansion capable of housing several pairs, but the shelter should in all cases be placed in an open location with a free sweep on all sides and well elevated. At present no attempt is made to attract these valuable birds by artificial nesting sites, but from their habits they should respond as readily as the species found in the United States.

Persons interested in watching birds about the house might attract some species by planting a few of the wild fruits of which they

are fond and which may be ascertained from the lists given on other pages of seeds identified in the stomachs examined. The majority of species of birds found in Porto Rico seem to be local in distribution; that is, they do not wander beyond their own immediate territory, and under proper encouragement and protection their numbers should greatly increase. The tendency is to cut away tree and brush growth at the borders of fields and on waste lands and so to decrease the available shelters for birds. With these conditions righted bird life should multiply and increase to the maximum which can exist on the island.

INTRODUCTION OF BIRDS.

Six species of birds are known to have been introduced in recent years into the island of Porto Rico, though only one, the hooded weaver finch (*Spermestes cucullata*), has spread over a large area. Of the others, the quail (*Colinus v. cubanensis*), introduced near Vega Baja, is apparently extinct; and the guinea fowl (*Numida meleagris*), known for many years as feral on this island, is very rare. The South American troupial (*Icterus icterus*), though found in Gundlach's time in a few localities, has apparently vanished; while the scarlet-cheeked weaver finch (*Amandava melpoda*), unlike the other member of the same family, has been known for many years only from the southwestern corner of the island and is still restricted to that range. There are no records to show how, when, or by whom these birds were introduced. The turkey vulture (*Cathartes a. aura*), found near Guánica, has not extended its range, though conditions are favorable for it over the entire island. None of the exotic species acclimated are injurious, and one, the vulture, would be decidedly beneficial if more common. The hooded weaver finch, at present harmless and living almost entirely on grass seeds, might, if rice culture were again attempted on a large scale, do considerable damage.

After a careful study of the conditions the introduction of insectivorous or frugivorous species would seem to the writer to be of doubtful value. Only species of economic importance will here be considered. To cope with the island insect pests at present attracting attention, the birds would have to be of moderate size at least. In addition to this they would have to be brought in from near-by islands or from continental tropical areas. In the present state of our knowledge concerning the food habits and general economy of tropical forms not a single species can be confidently recommended.

Too little is known of the food of tropical birds to merit their introduction into Porto Rico. Flycatchers, cotingas, becards, or members of the family of troupials, brought from the continent or other islands within the Torrid Zone, might prove to be almost entirely

frugivorous or develop an abnormal appetite for the abundant lizards and tree toads, which already suffer enough from the depredations of native forms of bird life and under the added weight of new enemies might be exterminated.

It is very doubtful if birds of well-known habits introduced from the United States would breed and rear their young under tropical conditions. Only an occasional species seems able to sustain itself when subjected to a new environment, and in order to do so it must be capable of assimilating a somewhat omnivorous diet, as forms specialized in regard to food or habits are almost certain to perish.

Should it be desired, however, to experiment in the introduction of extralimital birds, the barn owl (*Tyto perlata*) is recommended, as this bird is almost cosmopolitan in its range. Raptorial species are rare on the island, and as the fondness of the barn owl for rats is well known it is likely to prove a profitable introduction. In case the attempt is made, birds should be secured from Cuba or Jamaica or from as far south in the United States as possible, and shelters in the form of dove cotes should be provided for them in secluded places bordering the cane fields. It would be necessary to supply them with a small quantity of food until they become accustomed to the change of environment and could become self-supporting.

Should the birds increase, other shelters would have to be provided, as natural cavities are not found in sufficient numbers.

At present no species capable of coping with the change or caculo can be suggested which would thrive on the island and not be destructive to other interests. In clearing any circumscribed territory of its original forest and introducing methods of agriculture more or less intensive, great changes are wrought in the relations of the manifold interdependent forms of life found therein. This is shown plainly in the bird life of the island of Porto Rico. Certain species entirely dependent upon forest conditions for a suitable habitat have become very rare or in some cases extinct. Others more plastic, changing their haunts in conforming with new conditions, have held their own, or, in a few cases, have increased in number. It can not be supposed that in pre-Columbian times, when the island was entirely covered with trees, such birds of the open as the blackbird, ani, and gray kingbird were found in anything like their present numbers. Happily, the disappearing species are not highly beneficial and their place is filled by individuals of much greater economic value. To introduce a number of foreign species when nature is striving to attain equilibrium would only cause further disruption and disturbance. Energies should rather be directed toward the increase in number of the native birds, whose habits are better known and understood.

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To Mr. J. T. Crawley, who during the period when I was in Porto Rico was director of the sugar experiment station at Río Piedras, and who originated the present movement for bird protection and conservation in the island, I am deeply indebted for information and aid. Mr. D. L. Van Dine, at that time entomologist under Mr. Crawley, gave me material assistance in many ways, and the other members of the staff at the sugar experiment station were equally obliging. Mr. W. V. Tower, director of the Insular Experiment Station, who was then entomologist for the board of commissioners of agriculture, allowed me the use of his office as headquarters and rendered every assistance in his power. He was seconded during the latter part of my stay by his assistant, Mr. S. S. Crossman. Without Mr. Tower's aid the work would have been greatly handicapped and undoubtedly much prolonged. Mr. George Shanton, chief of police of Porto Rico, gave me a general letter to the men under him, which obviated many annoyances and inconveniences, and without which field work would have been impossible.

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In working up the collection of skins made during the field work, Dr. C. W. Richmond, acting curator of birds of the United States National Museum, rendered all possible assistance and placed at my disposal his personal notes made in Porto Rico; while Mr. J. H. Riley, of the division of birds, gave me a large number of titles bearing on Porto Rican ornithology and assisted in other ways.

ANNOTATED LIST OF SPECIES.

FOREWORD.

The species of birds discussed in the following pages comprise all those known at present to inhabit or to visit Porto Rico. For each species are given the names under which it is known, a brief account of its habits, and a statement regarding its food and economic status. Where deemed advisable, detailed lists of insects and other animals, seeds, and fruits identified in the stomachs are given in systematic order, so that as the status of other forms of life becomes known the relation of the birds to them may be more easily ascertained. Birds which have been enumerated by previous authors, but the occurrence of which has been found to be doubtful, have been included in brackets, with a brief summary of their status. A bibliography of important titles referred to in the preparation of this paper is given and, though not exhaustive, will prove of value. In citations reference is made to author, year of publication, and page. In case of two titles by the same author in one year, the second is distinguished by the letter a, following the year.

ANTILLEAN GREBE. *Podilymbus podiceps antillarum* Bangs.
ZARAMAGO, ZARAMAGULLON, SARAMAGULLON.

The Antillean grebe is known in the lagoons along the coast, but is retiring and seldom seen. In some of the large lagoons it is resident, though migrants undoubtedly occur in the winter months. At the Laguna de Guanica these birds were fairly common the last of May and very wild from much hunting. July 9 I saw two pairs on a large lagoon northeast of Manati that were evidently mated. As I walked along the shore they swam out, two together, with the male bowing and nodding, advancing and retreating before the female, cackling loudly, *kah kah kah*. One pair was seen feeding offshore, diving regularly in the shallow water.

They occur at times in very small sloughs where there is an abundant growth of water plants to protect them, as in the charcos along the Bayamon River, near Bayamon. Here they are seen only by chance, perhaps merely a ripple in the water betraying their passage in the dense vegetation.

Food.—The stomach of a single bird collected at the Laguna de Manati July 9 contained fragments of 2 dragon flies and more than 25 small crawfish. Besides this there was the large mass of feathers always found in grebe stomachs, in the present case forming more than 65 per cent of its contents. Bowdish (1902-3, p. 357) found the remains of three crawfish in one stomach, together with a small quantity of "mammal hair," which may have been the feathers alluded to. From such meager data the grebe appears to be beneficial in Porto Rico as elsewhere.

WEST INDIAN GREBE. *Colymbus dominicus dominicus* (Linnaeus).
TIGUA, SARAMAGULLON, ZARAMAGULLON.

The West Indian grebe is undoubtedly a rare resident in Porto Rico, for while small grebes are reported from several localities none were seen. Gundlach (1878, p. 395) found them at the Laguna de Guanica. Stahl (1887, p. 453) evidently did not consider them resident, as he says that they occur on the ponds

in winter. Richmond (MS.) notes specimens in a collection of birds in San Juan, taken by Stahl. In general this species is said to resemble the Antillean grebe, and probably agrees with it in food habits.

[RED-BILLED TROPIC BIRD. *Phaëthon æthereus* Linnæus.
GALLINAZA.

The red-billed tropic bird is uncertainly attributed to Porto Rico, though there is reason to suppose that it occurs occasionally at least. Catesby (1743, p. 14, Appendix) said that the birds bred in great numbers on some little islands at the east end of Porto Rico. Taylor (1864, p. 172) remarks under this species that he frequently saw tropic-birds flying about the harbor of San Juan, and all later authors appear to have quoted him. In habits, food, and general appearance it is said to resemble the yellow-billed species.]

YELLOW-BILLED TROPIC BIRD. *Phaëthon americanus* Grant.
GALLINAZA, GAVIOTA, RABIJUNCO, CHIRRE DE ALTURA.

The yellow-billed tropic bird is fairly common around Porto Rico. On the wing it is very strong and graceful, beating back and forth with long tail feathers blowing in the wind. The call note is a harsh, gull-like *kik*.

July 5 three were seen near some rocky cliffs north of Quebradillas, where they circled with rapidly beating wings about 40 feet above the water, swinging far out to sea and then returning to the shore. Gundlach (1878, p. 419) found them nesting on the rocky cliffs in this same locality. He secured fresh eggs April 5, and describes the plumage of the young.

Food.—Of two stomachs of this species available for examination one was entirely empty, though the bird was taken in the midforenoon. The other contained a few remains of fish bones. Fish undoubtedly form the great share of their food. The birds are too few to be of economic importance and the fish eaten are of little value.

BROWN PELICAN. *Pelecanus occidentalis* Linnæus.
ALCATRAZ.

The brown pelican is common in the coastal region of Porto Rico, Vieques, and Culebra, but is not known around Desecheo and Mona Islands, where shallow protected bays are lacking. The birds occur more commonly where there is shoal water over reefs, or in bays where small fish are abundant. The nesting season probably begins in February and extends to September (Gundlach, 1878, p. 416). Richmond (MS.) saw a young bird in a store window in San Juan March 29, 1900. Specimens seen in April and May had the seal-brown feathers of the nuptial plumage on the back of the neck. The birds are said to breed in June on sandy keys off the Playa at Humacao, and on the low flat islet known as Caballo Blanco at the entrance of Port Mulas, Vieques Island. On May 8 at Yabucoa a young bird three-quarters grown and well covered with fine gray down was seen on a mud bank at the mouth of a river. It showed no fear and was easily caught. When examined it objected by snapping the bill loudly, but did not attempt to bite. Upon being released it merely swam off a few feet and then remained quiet on the surface of the water.

Food.—The stomach and pouch of a specimen examined in the field contained small fish only, and these apparently form the entire food. Unless about a fish hatchery (and there are none at present in the islands) they are harmless and worthy of protection. Though the fish taken are commonly used as food by man, they are so abundant that the few eaten by the pelicans are negligible.

RED-FOOTED BOOBY. *Sula piscator* (Linnæus).
PAJARO BOBO.

Red-footed boobies were seen on Desecheo Island from June 13 to 16 and were much fewer in number than the common booby. Those on the island,

about 2,000 in all, were gathered in a close colony 200 feet above the water among growths of West Indian birch (*Elaphrium simarubra*) and other shrubs. The adults in white plumage were very conspicuous and were much wilder than either the young or the other species of booby. From *S. leucogastra* they can readily be distinguished by their smaller size, even on the wing. Second-year birds in a grayish plumage with white tail and undertail coverts were seemingly in pairs and ready to nest. These birds were much lighter on the wing than the larger species and rose with less effort. Their general habits were the same as those of the larger bird. They have not been recorded from Porto Rico before, though Bowdish (1902-3, p. 358) noted that there may have been a second species of booby on Desecheo Island at the time of his visits.

There is some uncertainty as to the breeding period of the two species of boobies here. Native fishermen say that they nest in October or December, while W. W. Brown, jr. (Cory 1892a, p. 229), found them nesting on Mona in February. From the condition of plumage in some of the young birds, they might have been hatched about that time, but others were evidently older. It is probable that some of the birds nest irregularly throughout the year, as the seasons are not sharply defined. In food and economy this species does not differ essentially from the common booby.

BOOBY. *Sula leucogastra* (Boddaert).

PAJARO BOBO, BUGUERE.

A booby rookery is reported on some rocky islets between Culebrita Island and Cayo Norte, the birds coming in the last of April and nesting through May and June. Men are said to gather their eggs occasionally, but the birds are probably not much disturbed. These birds are protected by law, as the small islands surrounding Culebra have been set aside as a national bird reservation and as such are under the jurisdiction of the United States Department of Agriculture.

Boobies are found at times along the coast of Vieques Island also, and on Desecheo Island this species is the most abundant bird, a conservative estimate made in June placing its numbers at from 8,000 to 10,000. These birds are said by the fishermen to nest here from late June until October, and a few were seen playing with sticks and straws as though contemplating nest building. So-called sportsmen have visited Desecheo occasionally and shot these helpless birds merely to see them drop. The veriest tyro can hardly miss one even on the wing. They are unfit for food, and, having little fear, circle repeatedly over those already killed.

Field examinations of stomachs of boobies showed only remains of fish, though marine invertebrates doubtless are taken to some extent. Passing their lives about these remote islands, the fish eaten by them are of little or no economic importance, even though the birds are numerous. The colonies here are now safe under Federal protection, and the birds should maintain their numbers.

MAN-O'-WAR BIRD. *Fregata magnificens* Matthews.

RABIJUNCO, RABIHORCADO, TIJEILLA.

The rabijunco is well known to the fishermen around the coast line of Porto Rico and its appearance is supposed by some to presage a storm. About Vieques and Culebra Islands they were occasionally noted soaring high over the ocean, usually well out from land. At Culebra, on April 11, one flew down and picked up a dead tropic bird which I had shot, but dropped it after carrying it a few feet. On another occasion in half a gale one flew over the town

of Playa Sardine in pursuit of a royal tern, calling *kik kik kik* sharply. The tern zigzagged back and forth, but its pursuer followed without apparent effort, although it finally gave up the chase. August 1 an adult female was seen in San Juan Harbor, circling over the marina and custom-house, curiously watching men at work on the water front. Bowdish (1902-3, p. 359, and in MS.) states that he found an abundant breeding colony on Mona Island.

On Desecheo Island from June 13 to 16 there were about 175 adults, all having young three-quarters grown. The majority of the young, one in a nest, were well feathered except about the head, although two were still entirely covered by down. The eggs are said to be laid in October. Four breeding colonies were located on the island, three of them within 400 feet of the water, and one near the top of the highest hill. The young sat quietly on the small platform nests with heads drawn in on the shoulders, but when I came near they clattered their bills loudly, and, snapping and squealing, gave up peace offerings in the form of unsavory masses of partly digested fish, while they crowded back, taking care, however, not to leave the nest. When nests were close together the young were continually fencing with their bills, rattling them loudly, and flapping their wings. One that I kept at camp was always ready to fight, but spent its time when undisturbed in sleeping or resting quietly with head drawn in on the shoulders. The food of the birds was entirely small fish, though the one at camp occasionally swallowed bits of meat. Usually, however, even when placed far down in the throat, meat was ejected by shaking the head violently sidewise.

Family cares did not seem to weigh heavily upon the adults. In the early morning they were at the nests, but were always on the wing by full daylight, and from then until evening passed most of their time circling in flocks over the island. As nearly as could be ascertained, the young were fed morning and evening and were seldom visited during the rest of the day. Sometimes three flocks of adults were seen circling slowly around, the highest mere specks in the sky. At dusk the birds returned with squealing calls, and there was considerable uproar in the rookeries until all were settled. Usually the long forked tail was held closed in flight, but occasionally was opened and shut scissors fashion.

These birds may at times be predacious, as shown by the actions of the one which attempted to carry off the tropic bird, and by their habit of pursuing gulls, terns, and possibly boobies, for the food that they may disgorge. The same remarks apply to their economic status as to that of the booby.

YELLOW-CROWNED NIGHT HERON. *Nyctanassa violacea* (Linnæus).
YABOA, YABOA REAL, GUANABA.

The yellow-crowned night heron is apparently becoming rather rare in Porto Rico. Gundlach (1878, p. 363) records it as common, and Bowdish (1902-3, p. 359) also so speaks of it in the localities that he visited. He found it even on Mona Island in August, 1901. It is a bird well known in the coast region, and the fact that it is considered a game bird and prized for the table explains its lessening numbers. The bird inhabits the mangroves and heavy forests covering the swamps, and near Mameyes one was flushed from a coconut palm. In the mangroves they sometimes slip away on foot and hide.

The single stomach examined was taken in the middle of the day and was entirely empty. Bowdish (loc. cit.), however, found fiddler crabs, two eels, and two crawfish in stomachs which he opened. From these meager data the food of the birds would not seem to differ materially from that of other herons. Detailed examination might show that they feed to some extent on the mole cricket. For the present at least they should be removed from the list of game birds and afforded protection.

BLACK-CROWNED NIGHT HERON. *Nycticorax nycticorax navius* (Boddaert).
YABOA, YABOA REAL.

The black-crowned night heron was apparently fairly common at one time in Porto Rico, though there are no recent records of its occurrence. Sundevall (1869, p. 602) received a single specimen from Hjalmarson, and Gundlach (1874, p. 313) records it as in Hjalmarson's collection in Arecibo. Gundlach also (1878a, pp. 161, 187) notes specimens taken by himself and says (1878, p. 362) that it was not rare. Stahl (1883, p. 150) had five specimens in his collection. Beyond this nothing is known of its occurrence.

LITTLE GREEN HERON. *Butorides virescens virescens* (Linnæus).
MARTINETE.

A specimen of the little green heron in the United States National Museum, taken at Fajardo, February 16, 1899, by A. B. Baker, has been identified by Oberholser (1912a, p. 540) as this subspecies. This is the only record at present for the West Indies.

CUBAN GREEN HERON. *Butorides virescens cubanus* Oberholser. (PLATES III and IV.)
MARTINETE, AGUALTA-CAIMAN.

The Cuban green heron is one of the commonest birds in Porto Rico and is distributed all through the coastal plain. On the northwest coast at Quebradillas and along the south coast in the dry regions they frequent the borders of streams mainly, though found occasionally in dry upland pastures (Quebradillas). The irrigated lands of the south coast are peculiarly adapted to their needs, and along ditches and channels in the fields they feed in abundance. In the lagoon region their centers of distribution were in the mangroves and swamps, and from these they spread into the surrounding cultivated lands. At Yabucoa they fairly swarmed in such localities and did an incalculable amount of good. After the breeding season they seem to wander inland. On Vieques they were tolerably common about the lagoons, but only a few were seen on Culebra. May 8, at Yabucoa, the number seen was estimated at between 1,500 and 2,000, all breeding adults.

Clumps of bamboos along streams were favorite perches. To these growths numbers retired to escape the burning heat of the midday sun, and in many localities they were used as nesting sites. Most of these birds, however, still nest in the mangroves and swampy growths bordering lagoons and lowland streams.

The breeding season extends from the first of February to the end of May and the young are well grown by July 1. The nests are simple structures of sticks. One examined May 8 near Yabucoa contained three fresh eggs of a pale greenish color marked with lime deposits on the shell.

Green herons are nearly always tame, unsuspicious birds, and seldom fly until closely approached, except in regions where they are much hunted. When they do flush, they rise with a series of squawking notes and before going far light on the ground again, on a fence post, or the limb of a tree. Sometimes they endeavor to escape notice by drawing the body up, pointing the bill straight in the air and presenting the striped breast to the observer. In feeding they follow slowly along the borders of marshes and lagoons, never wading in deeper water, as do the larger long-legged herons, or follow along the rows in the cultivated cane fields. Open pastures are favorite localities also, and here they work through the short grass, preferring low damp localities, but not neglecting those high and dry. Unless very hungry they are rather sluggish, and frequently spend an hour or more standing motionless with the neck drawn in.

The ordinary note is a harsh squawk, though frequently after alighting they give a clucking note, while a note of anger may be represented by *kek*

kek chuck chuck. A gunshot along a stream where they are common always calls forth a series of protesting squawks from birds hidden in clumps of bamboos and at the edge of the water. At the end of the breeding season, after the first of July, the young birds were abundant and were continually harried and pursued by the adults, which flew after them in the air or ran at them on the ground with open mouths, so that only in the bushes were they safe.

Where slopes along the streams are steep, as at Comerio, the birds remain close to the water. In more level localities they wander a great deal.

Food.—Fifty-one stomachs, collected from December to August, were available in studying the food of this bird. In these animal matter made up 99.18 per cent and vegetable 0.82 per cent. Orthoptera and crustacea form a large part of the animal food, and the vegetable matter is merely rubbish.

Animal food.—The destructive mole cricket (*Scapteriscus didactylus*), so well known in Porto Rico, forms 54.33 per cent of the total food of the period. No other bird of the Porto Rican avifauna eats them to such a large extent. They appear in 31 of the stomachs examined and in some make up the entire content. Three stomachs taken in January and two in August contain little else, while the smallest proportion, 13 per cent, occurs in the month of June. Both adults and nymphs were eaten, and one stomach contained 9 of the insects, while another had 11 pairs of jaws in it. Other orthopteran remains, amounting to 5.92 per cent, were found in 12 birds, and in 8 the remains were those of Locustidæ. One stomach contained a large grasshopper identified as *Neconocephalus macropterus*, another a locust (*Plectrotettix gregarius*), and another a cricket (*Gryllus assimilis*). Dragon-fly larvæ, with the abdomen of one adult and several damselflies, were found in 12 stomachs and figure as 3.84 per cent of the food. Insects of other orders formed but 6.73 per cent. One stomach contained a predacious diving beetle (*Acilius circumscriptus*), another a click beetle (*Drasterius* sp.), a third a small lamellicorn (*Atenius gracilis*), while a water scavenger beetle (*Tropisternus collaris*) and larvæ of others occurred five times. Aquatic bugs were found in nine cases, water bugs and back swimmers being best represented, while one water strider (*Gerris marginata*) was identified. Moth remains and a caterpillar represent the Lepidoptera, and one bird had eaten an ant. Other insect remains comprised Neuroptera in three stomachs and Diptera in three others.

Although fish remains appeared in 16 cases, they form only 9.52 per cent of the food. Small killifishes and gobies (*Dormitator* sp.) were found, all of small size. Crustacea had been eaten by 18 of the birds, small crabs in two stomachs and crawfish (*Macrobrachium olfersii*, *Xiphocaris elongata*, and others) in the remainder, forming in all 14.71 per cent. Five stomachs contained lizards of the genus *Anolis*, constituting but 1.15 per cent of the food. One was specifically identified as *Anolis pulchellus*. Three stomachs contained bones of the little tropical frogs *Leptodactylus albilabris*, known universally in Porto Rico as ranas, and these formed 0.61 per cent. Miscellaneous animal matter, consisting of spiders, a copepod, a marine annelid, and aquatic worms, amounted to 2.37 per cent for the nine months represented.

Vegetable food.—Vegetable matter, almost entirely accidental, was found in 11 stomachs. A few seeds of purslane (*Portulaca oleracea*) and two seeds not identified had been eaten by one bird, but the large part of the vegetable matter consisted of bits of grass and vegetable fiber. Only one immature bird had eaten a large amount of vegetable matter.

Owing to its unsuspicious nature and the ease with which it can be killed, the green heron suffers more than any other heron at the hands of "sportsmen," but the bird is of the greatest economic importance and one that should be protected at all times. The small portion of rather unsavory meat on its body

is insufficient to warrant the hunting of a bird which from the standpoint of the agriculturist is one of the most important species on the island. It should be protected, especially at nesting time, and encouraged by planting bamboos as permanent shelters along streams and drainage ditches. This species should hold its own and even increase largely, because of its adaptability to new conditions. The south coast especially, with the present area under irrigation and large projects under way, is very favorable to the green heron, and this bird is one of the few economic species especially adapted to that region.

LITTLE BLUE HERON. *Florida carulea carulescens* (Latham).

GARZA, GARZA AZUL.

The little blue heron, rather evenly distributed around the coasts of Porto Rico and absent or rare only where there are no marshy grounds or lagoon areas, was perhaps more abundant near Mameyes, Yabucoa, and Guanica than elsewhere. On Vieques it was the most common heron, and a few were seen on Culebra Island.

The birds inhabited lagoons, mangrove swamps, and marshy borders of rivers and were common in wet lowland cane fields. They often fed inland along the rivers and in the cane fields 3 or 4 miles from the coast. When disturbed, the ordinary note of the bird is a harsh *kar-r-rk*. The flight is strong and direct and in a high wind rather graceful. Nests which the birds had apparently just built were seen near Mameyes as early as February 9, while near Yabucoa a large colony had eggs the first of May. The nests were loosely constructed of twigs and were situated from 10 to 30 feet above the ground in mangroves and other trees in the swamps. The largest colony seen, near Yabucoa, contained over 150 pairs. In this rookery the birds left the nests when disturbed and circled overhead, some perching on dead limbs, craning their necks, and creating great bustle and general confusion. A mongoose, seen rather methodically searching the open ground under the trees, would without doubt have disposed of any fallen young. When breeding, the birds passed back and forth morning and afternoon to feeding grounds in the cane fields, many of them going several miles inland. When flushed in the cane fields, they returned to the coast region and did not light in the bamboos or other trees, to return to the ground later, as the green herons do. Sometimes after circling several times high in the air they dropped back a distance away to feed. Flocks of 15 or 20 sometimes waded out in shallow bays at low tide, searching for food, and when the tide came in retired to the mangroves.

After the breeding season little blue herons appear to spread out more and wander inland, occasionally as far as the base of the foothills, so that in August they were seen on the Guanajibos River below San German. Some birds go even farther up along the streams. On Vieques Island they flew inland with regularity to feed in the dry pastures. Usually three or four came together soaring and sailing and then circled slowly to the ground, where they walked about looking for food. On Culebra Island one was found only occasionally in the mangroves.

Many birds in white and in pied plumage were seen, and many of those taken in February were molting.

When undisturbed, as near Mameyes on the northeast coast, they become very tame. When a boat passed through the channels, the herons flew out continually from the mangroves with a rush of wings and harsh calls, alarming all other denizens of the swamps.

Food.—Fifteen stomachs of the little blue heron taken in February, March, May, June, and August were found to contain animal matter to the extent of 97.22 per cent, leaving 2.78 per cent for vegetable content. Miscellaneous

insects, lizards, and crustaceans form the bulk of the animal food, while the vegetable matter is accidental rubbish secured with other food.

Animal food.—Mole crickets (*Scapteriscus didactylus*) make 7.23 per cent of the total and were found in six stomachs. In one bird taken at Yabucoa I counted 35 jaws, and in each of two others were found two entire adults. Other insects formed 31.51 per cent, so that nearly two-fifths of the food of this bird is taken from the great class Insecta, a surprising amount for a bird of such aquatic habit. Nymphs of grasshoppers and locusts were found in five stomachs and caterpillars in four. Water bugs and water striders figure in three instances and dragon-fly larvæ of the suborder Anisoptera twice. Water scavenger beetles occur five times and several were identified (*Hydrophilus* sp., *Stethorus ater*, *Tropisternus nimbatus*, and *Berosus* sp.). May beetles (*Lachnosterna* sp.) had been eaten by two birds and figure as 1 per cent of the food, while another scarabæid beetle was found in one instance. Only one insect belonging to the order Hymenoptera was found. Miscellaneous animal matter, composed of two frogs (*Leptodactylus albilabris*), one spider (*Tetragnatha antillana*), and some indeterminate material, forms 0.59 per cent.

Crustaceans were present in 8 of the 15 stomachs examined and form 27.4 per cent of the contents. Crabs of four species (*Uca pugnax rapax*, *Aratus pisonii*, *Sesarma (Holometopus) roberti*, and *Goniopsis cruentata*) were identified in five individuals. Two species of shrimps (*Macrobrachium acanthurus*, and *M. olfersii*) were noted four times. Lizards form 29.44 per cent, and are probably the food sought when the birds visit the inland pastures. Twenty-one small lizards (*Anolis* sp.) were found in one stomach, together with ground-up remains of several more. Another contained three lizards of larger size (*Anolis pulchellus*), and four the ameiva (*Ameiva exul*). A small goby was found in one stomach.

Vegetable food.—The vegetable food, 2.78 per cent, may be considered entirely as rubbish, though it included seeds of purslane (*Portulaca oleracea*) and one other species. The great portion, however, was merely taken in with other food and in no case forms an appreciable bulk of the stomach contents.

The practice in many localities of treating these herons as game birds is to be deplored, as they are highly beneficial. At Yabucoa it was common for parties to hunt "garzas," and, although the little green heron suffered too, the blue heron, being larger, was more prized for the table. Their breeding grounds everywhere are being encroached upon by the charcoal burners, who are cutting the mangroves, and unless measures favorable to these herons are adopted a bird of considerable economic importance will be lost to the island. Men were seen busily engaged in cutting trees near the largest colony, and in a short time would have reached the rookery itself. By making reserves of some of the places occupied by the herons and by forbidding their hunting at all times their numbers should materially increase. Their flesh is inferior at best, and as for "sport," such a term can hardly be used in connection with the pursuit of large straight-flying birds like these, even though much hunting has made them rather wary.

The harm done by the birds in the destruction of lizards is greatly outweighed by good done in other directions, and lizards, except in case of the ameiva, do not seem to be decreasing in numbers. The value of this heron to the agriculturist lies in its destruction of the mole cricket and other injurious insects.

LOUISIANA HERON. *Hydranassa tricolor ruficollis* (Gosse).

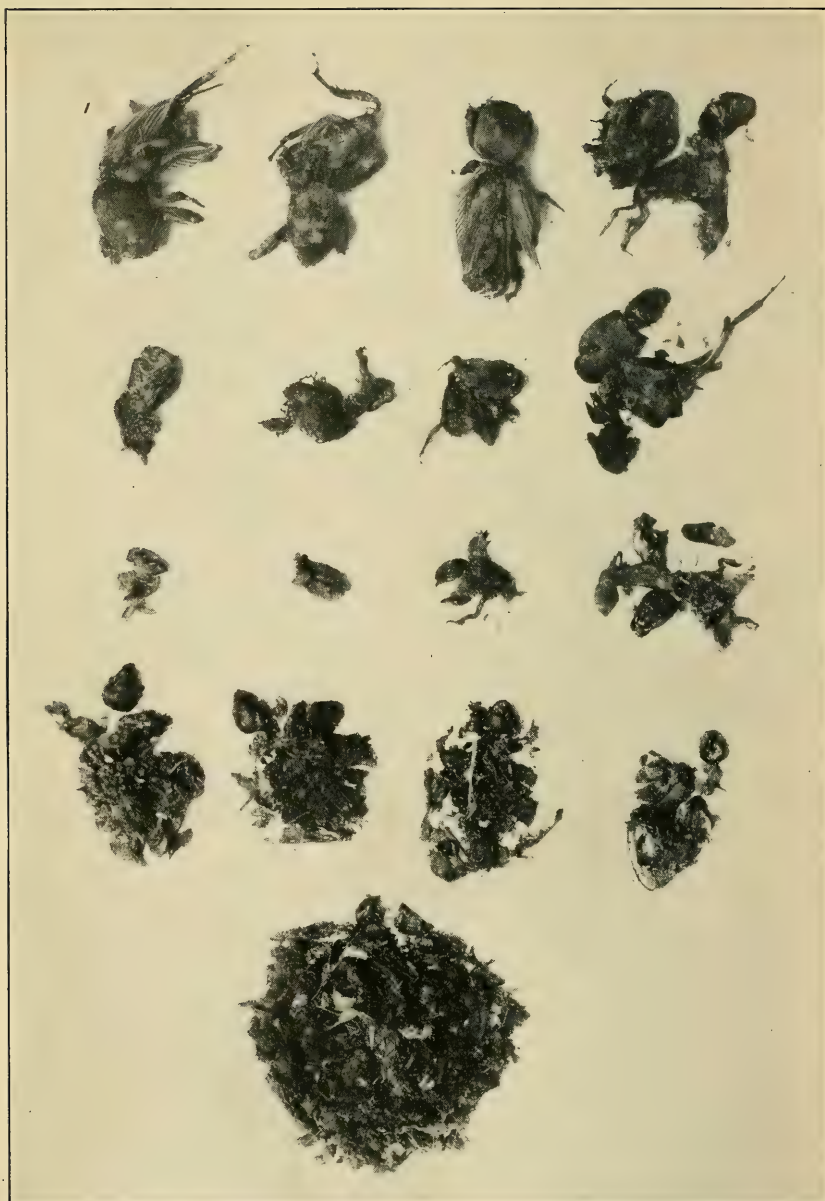
GARZA, GARZA DE CUELLO ROJO.

Gundlach (1878, p. 356) found the Louisiana heron only on the southwest coast at Boqueron, where it was common. In the present work the species was



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CUBAN GREEN HERON, OR MARTINETE (*BUTORIDES VIRESCENS CUBANUS*).



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STOMACH CONTENTS OF A CUBAN GREEN HERON, OR MARTINETE (*BUTORIDES VIRESCENS CUBANUS*.)

The martinete ranks first among the bird enemies of the mole cricket, or changa (*Scapteriscus didactylus*). Sixteen entire changas and fragments of others were found in one stomach.

seen in the lagoon region between Salinas and Guayama, where on May 3 several were wading in shallow bays and pools. There are no other definite localities recorded for it on the island. The single bird examined had eaten 16 small fish from 1 to 2 inches long, among which was 1 goby, the others being killifishes. These are all food fishes, but not of sufficient value to condemn the bird, as it is too rare here to do any appreciable damage.

SNOWY EGRET, SNOWY HERON. *Egretta candidissima candidissima* (Gmelin).
GARZA, GARZA BLANCA.

The snowy egret is resident in Porto Rico, being distributed throughout the lagoons of the coastal region and about the mouths of the rivers, usually ranging 3 miles or more inland. After the breeding season the birds appear to wander, as on August 8 one was seen flying up the Rio Vivi at Utuado. While still fairly common, especially in the large, more inaccessible swampy regions, the egret has suffered much at the hands of plume hunters, and I was told that as late as 1910 plumes had been offered for sale in Caguas.

March 16 about a dozen were seen on Piñero Island, off Fajardo, where they are said to breed. At Salinas the birds were said to be nesting on low mangrove-covered islands lying offshore, and parties of three and four were seen flying back and forth between these islands and the mainland, frequently 200 feet in the air.

In the lagoons snowy herons joined other larger species at low tide, wading in shallows over the reefs in the bays, or at the borders of the lagoons, in water nearly up to their bodies. Where they are much hunted these birds are very wary and, seeming to appreciate that their white color renders them conspicuous, are the first among the herons to take alarm. When they leave they usually frighten the others. They may readily be distinguished from white immature specimens of *Florida c. cærulescens*, as they have the tarsus black and the soles of the feet yellow, while in the little blue heron the tarsus is greenish. Frequently the snowy egret feeds in lowland cane fields, especially when these are wet or partly flooded. Often in flocks of three or four they feed in the dry upland pastures.

Food.—Two stomachs were available for examination, both of birds which had been feeding in mangrove swamps. The main content of these is animal matter, vegetable remains occurring only as rubbish secured with other food and amounting to but 1 per cent. One bird taken near Rio Piedras had eaten two dragon-fly nymphs, a small crab, a lizard, and a small frog. The stomach of the other, secured near Mameyes, was nearly filled with bones of small gobies, the remainder of the animal food consisting of fragments of flies of the family Dolichopodidæ and bits of a grasshopper. In their excursions to drier fields the birds must secure other insects. They feed to a large extent upon fish, but the fishes taken are of no great importance and the birds are not abundant enough to become noxious. They have been found worthy of protection in the United States, and the same course should be followed in Porto Rico in hope that they will increase in numbers, when they may assist in holding in check the destructive mole cricket.

EGRET. *Herodias egretta* (Gmelin).
GARZON BLANCO, GARZA REAL.

A few of the large egrets are still found in the lagoons of the coastal region of Porto Rico, but they are nowhere common. On February 14, while I was crossing Comezon Cove near Mameyes, a fine egret flew out from a nest in an isolated clump of mangroves. The nest was merely a loose platform of sticks about 20 feet from the water and contained one young bird and two added

eggs. On Piñero Island, near Fajardo, there was a colony of about 15 or 20, and these were said to breed there every year.

The birds usually are seen at low tide wading in the shallow lagoons in water well up to their bodies, where they work slowly along, looking for food; or are seen flying, two or three together, above the surface of the water. They are nearly always shy and hard to approach. Formerly much hunted for their plumes, they are now so few that the work does not pay, and they are molested only by occasional hunters.

Food.—The single stomach available for examination contained 4 per cent of vegetable rubbish taken as extraneous matter with the animal food. Remains of one mole cricket (*Scapteriscus didactylus*) and seven entire grasshoppers, with fragments of many more, were found, as well as a moth and three large dragon flies. A small goby and seven entire frogs (*Leptodactylus albilabris*), with fragments of others, made up 69 per cent of the contents. Orthoptera amounted to 15 per cent, a surprising fact and one that should be given due weight in considering the status of this species. The egret should be accorded the fullest protection or it will disappear entirely from the avifauna of the island. For its beauty and its destruction of injurious insects it is entitled to preservation.

WEST INDIAN GREAT BLUE HERON. *Ardea herodias adoxa* Oberholser.
GARZON CENICIENTO, GARZON CENIZO.

The great blue heron is tolerably common in suitable localities in the coastal region, but apparently is merely a winter visitant. Gundlach (1878, p. 352) remarks on its nesting in the island in November and January, but gives no definite localities. It may be that the birds occasionally nest here, but the larger part of those found occur only in winter, and the summer stragglers may be nonbreeders. Only two were noted—at Guanica, May 26—though many favorable localities were visited. The few birds seen were shy, and it was difficult to approach them, as they have been hunted a great deal. Near Mameyes they passed much of the day in the more open portions of the mangrove swamps, where fiddler crabs (*Uca* sp.) were abundant, and they seemed to feed on them. At low tide they flew out to the shallow bays, beyond gunshot, to feed over the reefs, and kept a sharp lookout for intruders. Here they secured small fish and probably crabs. In some localities hunters prize this bird for the table, more because of its large size than its flavor. Although not known to be directly beneficial to agriculture in Porto Rico, it is worthy of protection, as it is not harmful under present conditions.

[GREAT WHITE HERON. *Ardea occidentalis* Audubon.
GARZON BLANCO.

No actual specimens of the great white heron are recorded, though at one time it may have been found in Porto Rico at least occasionally. Gundlach (1878, p. 354) says that it was reported from various localities, and states that a white heron seen at the border of the Laguna de Guanica (Nov., 1873) was so large that it could have been no other species. Don Tomas Blanco also knew of it near San Juan. Stahl (1883, p. 64) lists it without comment, and later records in literature appear to follow these.]

LEAST BITTERN. *Ixobrychus exilis exilis* (Gmelin).
MARTINETE CHICO, MARTINETE.

The least bittern is a resident species at present found only in a few localities along the coast. One was seen December 22 near Rio Piedras and at the Laguna de Guanica May 26 they were fairly common. Gundlach (1878a, p. 161) found them at Mayagüez, Arecibo, and along the Rio Toa at Dorado. One was taken at Porto Real (near Cabo Rojo) January 27, 1899, by Dr. J. D.

Milligan, of the U. S. S. *Fish Hawk*. At the Laguna de Guanica they are undoubtedly resident, as there are large areas of grassy marshes and many open stretches filled with growths of the water plants they prefer. Here the birds were rather wild and hard to approach, as they are molested a great deal by egg hunters. They are found in the grass where the water is from 1 to 2 feet deep and flush with dangling feet and outstretched neck. Almost at once the feet are drawn up, the head is doubled back onto the shoulders, and the birds fly off just above the vegetation, to drop back again when out of danger. When undisturbed, they sit quietly in the reeds or with long strides clamber rather awkwardly through them, grasping the stems in their slender toes. Gundlach (1878, p. 350) found a nest containing three eggs at Arecibo May 7. The bird seen at Rio Piedras was in a mangrove swamp, but as that is rather an unusual locality for them this individual may have been a migrant.

Food.—Three stomachs from the Laguna de Guanica contained nothing but animal matter. Remains of small fish in all the stomachs made up the large share of their contents (84.34 per cent). Crustacean remains in one formed 13.33 per cent, and a bit of an amphibian in one stomach figures as 0.33 per cent. Insect matter amounting to 2 per cent in two stomachs was made up entirely of fragments of aquatic Hemiptera. Quantities of feathers were found in all three stomachs, but they undoubtedly came from the bird itself. The bird thus seems to be about neutral from an economic standpoint. In its food habits this bittern can not be regarded as injurious, as little or no use is made of the small fresh-water lagoon fish, while the crustaceans taken may be considered as a point in its favor. The birds are too retiring to attract much attention, but should be placed in the protected class.

BITTERN. *Botaurus lentiginosus* (Montagu).

YABOA.

Gundlach (1878a, p. 161) secured a bittern in November, 1873, at the Laguna de Guanica and also records one (1874, p. 313) in the collection of Blanco at San Juan. Stahl had none in his collection, and as no other specimens are on record the species must be regarded as a casual migrant to the island.

[GLOSSY IBIS. *Plegadis autumnalis* (Linnæus).

COCO, COCO OSCURO.

The glossy ibis is included here, as Gundlach (1878, p. 366) mentions a drawing of it in the album of Dr. Bello, of Mayagüez. Later records by Gundlach and others are all apparently based upon this, so that it can be given only as a hypothetical species.]

WHITE IBIS. *Guara alba* (Linnæus).

COCO BLANCO.

Gundlach (1878, p. 364) did not find the white ibis on the island, but says that it was reported from the northeastern portion. Stahl (1883, p. 64) listed it without comment, but later (1887, p. 452) mentions it as a solitary species seldom found. Richmond (MS.) notes a specimen from Porto Rico in the Stahl collection in San Juan, and this is all that is known regarding its occurrence here. Formerly it may have been a resident species, but it is no longer found.

FLAMINGO. *Phænicopterus ruber* Linnæus.

FLAMENCO.

The flamingo occurred formerly on Porto Rico and Culebra at least, and at an early date was fairly common. Now it is said to be found occasionally in the lagoons at Salinas and Aguirre, while stragglers are seen along the coast from Guayama to Ponce. In the extreme southwestern corner of the island

about El Boqueron and in the lagoons below it, the birds are also reported. None were seen in the course of the present work. Gundlach (1878, p. 398) found them at El Boqueron and on the south coast, and remarks that they are said to be common on the east coast and on the off-lying islands. Ledru (1810, p. 209) mentions them from the River Loisa.

MASKED DUCK. *Nomonyx dominicus* (Linnæus).

PATO CHORIZO, PATO DOMINICA.

The masked duck is probably a rare resident in Porto Rico, though there are no recent records for it. Gundlach (1878a, p. 162) took it at the Laguna de Guanica and saw it in the collection of Hjalmarson at Arecibo (reported by Sundevall 1869, p. 603) and in that of Blanco in San Juan. Stahl (1883, p. 65) records one specimen in his cabinet as taken in Porto Rico.

RUDDY DUCK. *Erismatura jamaicensis* (Gmelin).

PATO CHORIZO.

Ruddy ducks appear to be regular migrants to Porto Rico, though I did not see any. Gundlach (1878, p. 407) remarks that he found them "hatching" at the Laguna de Guanica in November, 1873, but says nothing more regarding their breeding. At the time of my visit in May, 1912, the Bahama pintail (*Pæcilonetta bahamensis*) was common and the only duck nesting there. Gundlach (loc. cit., 403) did not record the Bahama pintail nearer than Boqueron and it is possible that he may have attributed nests or young seen at Guanica to the wrong bird. Stahl (1887, p. 453) also remarks that the ruddy duck breeds in Porto Rico, but may have been quoting Gundlach's record. More definite information is necessary in order to recognize the ruddy duck as a breeding species.

BUFFLE-HEAD. *Charitonetta albeola* (Linnæus).

PATO PINTO.

A specimen of the buffle-head was found by Richmond (MS.) in Stahl's collection of birds, which he examined in San Juan. This is the only record for the island, and the bird must be considered an accidental visitor there. The only other West Indian record is of a bird found in the market in Habana, Cuba (Cooke, 1906, p. 52).

RING-NECKED DUCK. *Marila collaris* (Donovan).

PATO DEL MEDIO, PATO SILVESTRE.

The only certain records for the ring-necked duck in Porto Rico are those of Gundlach (1878, p. 406), who saw a specimen taken in winter near San Juan by Blanco, and (1878a, p. 162) also mentions one taken by himself. Stahl (1883, p. 65) includes it in his list without comment.

LESSER SCAUP DUCK. *Marila affinis* (Eyton).

PATO DEL MEDIO, PATO SILVESTRE, PATO MORISCO.

The lesser scaup duck is a winter resident and is probably common. Many ducks are said to occur on the lagoons of Porto Rico, Vieques, and Culebra during the wintertime, and it is probable that they are largely this species. Gundlach (1878, p. 405) found them common at Boqueron and the Laguna de Guanica, and Stahl (1883, p. 154) had specimens in his collection taken probably near San Juan. The only place at which this species was certainly identified was at the Laguna de Guanica, where a crippled bird was taken May 26. A flock of about a dozen seen in the open water on the same date probably were of the same species. In April ducks apparently of this species were on a lagoon known as Flamenco on Culebra Island.

Food.—The stomach of the single bird examined contained fragments of a water boatman (*Corixa* sp.), two water scavenger beetles and the larva of another, bits of an undetermined beetle, and many fragments of dragon-fly larvæ, the last item forming 69 per cent of the contents. Six grass seeds (*Panicum* sp.) and bits of two other seeds formed vegetable matter to the amount of 4 per cent.

A close season for all ducks should be established similar to that recommended for the Bahama pintail.

[PINTAIL. *Dafila acuta* (Linnæus).

PATO PESQUEZILARGO, PATO SILVESTRE.

Gundlach (1878, p. 402) says that the pintail is a winter visitant and that one was taken near Arecibo by a friend of his but that he did not see the bird himself. There is no certain record.]

BAHAMA PINTAIL, BAHAMA DUCK. *Pacilonetta bahamensis* (Linnæus).

PATO DE LA ORILLA, PATO CRIOLLO, PATO DE FLORIDA.

The Bahama pintail was noted on Culebra Island and at the Laguna de Guanica, but undoubtedly occurs in other favorable localities, especially in the winter season. Gundlach (1878, p. 403) found them at Boqueron and San Juan.

May 26 the birds were common at the Laguna de Guanica, where they would flush singly or in pairs from a growth of water plants covering a large area of the lagoon and, after circling over the open water, return to the same cover. Once in the short grass of a marsh a female flew out, but almost immediately fell back as though with a broken wing, repeating the performance several times. At the same time the low *peep peep* of young birds was heard and two about 5 days old were caught. A third promptly dived and apparently never came up, while the others rapidly scattered to safety through the grass. The down of these little birds was not at all soft, but had a peculiar stiff bristly feeling.

Food.—Stomachs of eight adults and two downy young which were collected were examined by W. L. McAtee, of the Biological Survey. The adults had eaten nothing but vegetable matter. Seeds of ditch grass (*Ruppia maritima*) were found in every stomach and formed 16.25 per cent of the total bulk, the largest amounts being 180 and 125 seeds, respectively. Foliage and antheridia of algæ (*Chara* sp.) made up 83.75 per cent and formed the great bulk in all the stomachs. The two downy young had eaten animal matter (amounting to 3.5 per cent), composed of remains of a water boatman (*Corixa* sp.), bits of a water creeper (*Pelocoris* sp.), and young snails. Grass seeds, foxtail grass (*Chaptachloa* sp.), barnyard grass (*Echinochloa crus-galli*), and a species of guinea grass (*Panicum* sp.) formed 94 per cent of the food of these ducklings and a few other seeds 2.5 per cent.

These birds were much disturbed by egg hunters who were continually searching the marshes, and many were shot by gunners during the breeding season. They should be free from molestation from March 1 to December 1 at least. In a few years their range will be even more restricted than at present, because of the draining and clearing of swamps and marshes, and unless protected they will disappear entirely.

SHOVELER. *Spatula clypeata* (Linnæus).

PATO INGLES, PATO CUCHARETA.

The shoveler is, from all accounts, a tolerably common winter visitor in Porto Rico. Gundlach (1878, p. 404) says that it is found from fall until

April, and there are several specimens on record. (Sundevall, 1869, p. 603; Stahl, 1883, p. 153.)

BLUE-WINGED TEAL. *Querquedula discors* (Linnæus).

PATO DE LA FLORIDA.

According to all reports this is a common winter visitant, being the most familiarly known duck, though I saw none. Gundlach (1878, p. 404) writes that it is abundant, arriving in September. There are also numerous records of specimens. It is to be looked for in fresh-water marshes and charcos as well as in larger lagoons.

BALDPATE. *Mareca americana* (Gmelin).

PATO LABLANCO.

The baldpate is a rare winter visitant in Porto Rico, being reported as occasional by duck hunters. Sundevall (1869, p. 603) records a young male sent him by Hjalmarson, and Gundlach (1878a, p. 162) secured a specimen, but assigns no definite locality.

BLACK-BELLIED TREE DUCK. *Dendrocygna autumnalis* (Linnæus).

YAGUAZA, CHIRIRIA.

The tree duck is well known to all Porto Ricans, but apparently has become very rare, as I did not see one. Taylor (1864, p. 172) found them abundant, and later authors record them as common, but they apparently represent a vanishing species. The species still exists, without doubt, in small numbers and needs absolute protection for a period of years if it is to be preserved as a game bird. The clearing and draining of many of the swamps has done much toward reducing its numbers by depriving it of cover. Gundlach (1878, p. 400) says that the birds feed at twilight, spending the day sleeping or under cover, and that they lay from 12 to 14 eggs. Sundevall (1869, p. 603) records them as nesting commonly in the island.

[GREATER SNOW GOOSE. *Chen hyperboreus nivalis* (J. R. Forster).

GANSO BLANCO, GUANANA.

It is said that white geese are occasionally found in fall on the lagoons at Manati and that they are sometimes killed. Thus they may be rare winter visitants. Gundlach (1878a, p. 190) heard of one captured at Isabela, while Stahl (1883, p. 65) merely remarks that they are rare. No authentic specimens are on record, so that the bird is included here as a hypothetical species.]

TURKEY VULTURE. *Cathartes aura aura* (Linnæus).

AURA, AURA TIÑOSA.

In the dry limestone hills above Guanica the turkey vulture was fairly common. It appeared to range casually from Añasco to Yauco, keeping near the coast, though once reported from the summit of the Mata Platano above Adjuntas. The species is said to have been introduced from Cuba into the southwestern part of the island by the Spanish Government (some say, incorrectly, by the Guanica Centrale), the exact date not being known. An old man near Yauco who had known them since boyhood stated that their numbers had neither increased nor decreased in that time. On one occasion 16 were counted circling over a dead bird, and as in such a small area all the birds present would be attracted by the circling of a flock their total number was certainly less than 25. There is no apparent reason for their not having increased and spread at least the entire length of the dry south coast, as the conditions there are apparently as favorable as in this region. Their beneficial habits are well known to the country people, so that they are not molested. Probably their only enemy is the mongoose.

Gundlach (1874, p. 307) says emphatically that the turkey vulture was not found in Porto Rico, so that we may consider it as introduced since his travels on the island, as he visited the region about Guanica in November, 1873. A. B. Baker (MS.) saw several during the latter part of January, 1899.

PORTO RICAN SPARROW HAWK. *Falco sparverius loquacula* Riley.
FALCON.

Dry areas with a rather open brush growth, as on the south coast of Porto Rico, were apparently very favorable to the Porto Rican sparrow hawk, and in some of these localities the birds were almost abundant. On Porto Rico a few were found scattered through the coconut groves along the coast, but they were more common in the foothills, and inland on the north coast few were seen below 1,000 feet elevation. They are also common on Vieques and Culebra. Few were found in the cane fields, as commanding perches from which to watch for food were lacking, but they were common about openings in the coffee plantations.

Sparrow hawks began to breed about April 1 and were nesting through May and June. Many young birds under their parents' care were found during July and August, when they remained quiet in perches shaded from the glare of the sun, chiefly in the coffee plantations. When abandoned by the adults, the young birds were very noisy and restless, giving voice to their displeasure continually. The nests were in cavities in palms and other trees. Many adults taken during the breeding season had the tips of the rectrices much abraded from wear in the nesting cavity or from bracing on the tree trunks before the entrance. A female taken near Salinas, April 30, contained an egg almost developed. Fragments of the shell were whitish with scattered cinnamon spots, but whether or not all of the color had been deposited could not be determined. Three young were the greatest number observed in one party, though Gundlach (1878, p. 163) says that from three to five eggs are laid. The birds uttered a sharp *killy killy killy*, and during the early part of the nesting season especially were very noisy. On Culebra Island one was seen pursuing a red-tailed hawk and screaming shrilly.

From field observations these little hawks fed largely on lizards picked up easily from the ground or captured on fence posts, stumps, or tree trunks. One taken at the old naval encampment on Culebra Island had eaten a common house mouse. Sparrow hawks were seen on several occasions in pursuit of woodpeckers, doves, or yellow-shouldered blackbirds, but none were observed eating or holding birds that were certainly identified as such. A. B. Baker (MS.) saw one strike an ani in a bush and bear it to the ground. Ground doves were the only birds that showed great fear of them. Near Quebradillas on July 3 a sparrow hawk swung down under an overhanging ledge with a low chattering call and examined several cliff swallows' nests, but they were apparently empty.

Food.—Forty-eight stomachs of the sparrow hawk were examined, taken from January to August, inclusive. Animal food made up 99.68 per cent, and vegetable 0.32 per cent. The vegetable matter, composed entirely of rubbish, was found in three stomachs and need not be considered, as it was not actually taken as food.

Mole crickets (*Scapteriscus didactylus*) were found in 17 stomachs and made up 28.69 per cent of the total food. One bird had eaten four of these destructive insects, another three, and several had taken two. They were found in every month represented, except August, and occurred constantly in a large series collected in March and April. Other Orthoptera formed 20.86 per cent and were composed mainly of locusts (Acrididæ) with a good many katydids (Locustidæ).

Remains of small birds in two stomachs amounted to 1.88 per cent. One stomach contained portions of a Porto Rican grosbeak (*Loxia portoricensis*) and another a small black feather only; there is evidently some basis for the fear shown these hawks. House mice (*Mus musculus*) were found in eight stomachs and formed 5.59 per cent. They were noted in stomachs taken in March, April, and May only. The only real criticism of this small hawk is its large consumption of lizards, amounting to 40.4 per cent of its entire food. One ameiva (*Ameiva exul*) was taken, but the great mass was made up of the ever-abundant anolis, of which four species were definitely identified (*Anolis cristatellus*, *A. gundlachi*, *A. krugi*, and *A. pulchellus*). Unless of small size, they were usually pulled in two before being swallowed. Miscellaneous animal matter composed largely of spiders amounted to 2.26 per cent.

Under present conditions the sparrow hawk must be considered a valuable species, as it feeds so largely on the changa or mole cricket. Although many lizards, whose food is entirely insects, are taken, their numbers are so great that no impression is made upon them.

The number of mice eaten illustrates to what extent these rodents have overrun the island. The sparrow hawk is not large enough to attack rats, except, perhaps, young animals. To encourage the birds about cane fields occasional high perches from which they can watch for prey should be provided along the fences. Their numbers should increase in the lowland region, as their natural food is abundant and easily obtained.

PIGEON HAWK. *Falco columbarius columbarius* Linnæus.
GAVILAN.

The pigeon hawk is a rare winter visitant to Porto Rico. Sundevall (1869, p. 601) received a single specimen from Hjalmarson, of Arecibo. Gundlach (1878, p. 162) saw one at the Laguna de Guanica and secured a female at Quebradillas. Stahl (1883, p. 136) had specimens in his collection, and Richmond (MS.) notes that a small hawk seen at the Hacienda Catalina, in March, 1900, may have been of this species. None were seen by me. It is fortunate that this little falcon is not more common, as it is one of the few species found that are injurious, its food being made up largely of small birds.

DUCK HAWK. *Falco peregrinus anatum* Bonaparte.
GABILAN, HALCON DE PATOS.

Gundlach (1878, p. 161) notes seeing a duck hawk repeatedly at the Laguna de Guanica in November, 1873, where it was feeding on ducks and coots. Stahl (1883, pp. 58, 136) found this species about the lagoons and had a female from Porto Rico in his collection. It is apparently a rare winter visitant, following the migrating water birds, and while not abundant enough to be of much damage should not be protected. Its food is almost entirely birds of various species.

BROAD-WINGED HAWK. *Buteo platypterus platypterus* (Vieillot).
GUARAGUOU DE SABANA.

The broad-winged hawk was formerly a common resident, mainly in the interior, according to Gundlach (1878, p. 160), who secured specimens. Richmond (MS.) saw one near Utuado April 6, 1900, and identified it certainly. This is the only recent record for the bird. Stahl (1883, p. 58) undoubtedly erroneously considered it a migrant. Gundlach (loc. cit.) reports its food as small reptiles, large insects, and birds. I did not see this hawk during my stay on the island and it is very rare at present.

RED-TAILED HAWK. *Buteo borealis* (Gmelin).

GUARAGUOU, GUARAGUOU DE SIERRA, LECHUZA.

Wherever there are steep hilltops still covered with second-growth forest to furnish safe retreats and nesting places, red-tailed hawks are a tolerably common resident species. These birds had the same call notes and habits as the northern forms, but were seldom seen except at a distance. Much persecution has made them wary, but so long as they have safe retreats they will continue to exist.

On January 18 one was seen carrying nesting material in the mountains above Cayey and a nest seen on Vieques Island the middle of March was said the week before to have contained two young two-thirds grown. Young birds were noted in July and August and an immature specimen was taken near Manati July 11. The birds were most active before 9 o'clock in the morning and after 3 in the afternoon, spending the heat of the day perched on dead trees.

Throughout the country these hawks are universally credited with eating chickens, though no specific instances were noted by the writer. Near Yabucoa one man claimed to have lost eight in a week. Before man's advent in this region the food of this bird must have consisted of lizards, snakes, and birds, as there were apparently no mammals except bats on the island. The present custom of allowing chickens to run in the fields and coffee plantations at considerable distances from houses leaves them open to attack, and there is not much doubt that a few at least are taken. Bowditch (1902-3, p. 361) notes the remains of rats in the only two stomachs examined by him. Land holders all conceded that the hawks ate many rats, and some that they ate crabs and lizards also. The country people secure the young hawks for food whenever possible.

From the few specimens at hand it is not possible to determine whether this species is allied to the Jamaican bird, or whether it is sufficiently distinct to merit a new name.

Food.—Two stomachs only of this species were examined and one was entirely empty. The other contained the hind quarters of a good-sized rat (*Eptimys* sp.), evidence in favor of the bird. Where individuals form the habit of eating chickens they should unquestionably be killed, but otherwise should not be molested.

PORTO RICAN SHARP-SHINNED HAWK. *Accipter striatus venator* Wetmore.¹
FALCON.

On May 30 a small hawk, which proved to be a new form, was taken at an elevation of about 1,500 feet back of Maricao. It came sailing overhead with something, presumably a bird, in its talons, and was mistaken at first for a sparrow hawk. Another individual was noted the same day, and on June 4 still another was seen in a dead tree eating a small bird. When shot this bird fell down a steep slope and was lost. Apparently these hawks are not only rare but are local, as the genus has not been recorded on the island up to this time, and individuals were found in this one locality only. Here they were frequenting steep slopes densely covered with coffee, while certain low mountains farther inland, covered with an almost impenetrable second growth, also may have harbored them.

Food.—From the foregoing it would seem that the food was mainly small birds, so that the species must be considered as injurious, though in the case of a bird numerically so weak this can hardly be considered of importance. The single stomach examined contained fragments of a Latimer's vireo (*Vireo*

¹ Proc. Biol. Soc. Washington, XXVII, 1914, pp. 119-122.

latimeri) as well as a few feathers of a honey creeper (*Cæreba portoricensis*), thus substantiating field observations.

OSPREY. *Pandion haliaëtus carolinensis* (Gmelin).

AGUILA, GUINCHO, AGUILA MARINA.

The osprey is apparently a rare winter visitant to this region. Bowdish (1902-3, p. 361) notes two from Vieques and one from Mona, while Gundlach (1878, p. 158) includes it on the authority of Blanco. Stahl (1883, pp. 58, 136) recorded it as a migrant about the mouths of rivers and had one specimen in his collection. Along the coast near Mameyes I saw several during February perched on stakes in the water or circling over the shallows and occasionally visiting swampy lagoons inland; one was seen on Culebra April 8 and another April 17. The osprey lives entirely on fish, but it is not numerous enough to be of economic importance.

GUINEA HEN. *Numida meleagris* Linnæus.

GALLINA DE GUINEA, GUINEA.

The guinea hen, formerly common in the forests, has become wild in Porto Rico as in the other Greater Antilles. Gundlach (1878, p. 352) records the birds as common, and says that their food consists of seeds, wild fruits, maize, rice, sweet potatoes, and plantains, and that sometimes they cause considerable damage to the latter crop. Ledru (1810, p. 207) says that the guinea hen was brought to Porto Rico by the Genoese slavers about the year 1508. Stahl (Richmond MS.) secured a specimen at Cabo Rojo many years ago, and Sundevall (1869, p. 601) says that they were not rare. At present they are confined to natural forest areas, as the Cerro Gordo near Maricao, in Caguana, near Barros, and on El Yunque de Luquillo. They are few in number and so wild and retiring that to secure them is largely a matter of chance. Formerly they were considered game birds and hunted systematically. With the clearing of the land and the loss of cover, only a small number will survive, and these in the most inaccessible regions. They are described as being darker than the domestic guinea hen and with a differently marked head.

CUBAN QUAIL. *Colinus virginianus cubanensis* (Gould).

CODORNIZ.

The Cuban quail was introduced into Porto Rico by Don Ramón Soler in the Hacienda Santa Ines near Vega Baja about 1860 (?) (Gundlach, 1878, p. 350). Stahl (1883, p. 149) had two specimens in his collection, and Hjalmarson also secured some (Sundevall, 1869, p. 601). Bowdish (1902-3, p. 360) saw one on a hill near Mayagüez, but now the bird is apparently extinct. I could not learn of any seen recently.

AMERICAN COOT, MUD HEN. *Fulica americana americana* Gmelin.

GALLINAZO, GALLARETA, YAGARETA, DAGARETA NEGRA.

The coot is found in Porto Rico, usually in flocks on the large lagoons. Many individuals appear to be migratory, but the species as a whole is resident. They were noted as very common on the Laguna de Guanica and on the large lagoon north of Manati. Two birds were seen on Culebra April 13 and 19, respectively. On the Laguna de Guanica May 26 a large number were apparently breeding. The country people searched the marshes systematically for their eggs, so that few escaped. On a large lagoon north of Manati and Vega Baja on July 9 a flock of 300 or 400 was noted, many of them young birds.

Food.—A coot taken on Culebra had eaten a water scavenger beetle, a number of small crustaceans, and a large mass of eggs belonging probably to other

crustaceans. Bits of wood and other vegetable matter were present in small quantities. A bird from Guanica, taken in May, had eaten a large quantity of grass or sedge, with a few small roots.

The coot, while not ranking high as a game bird, possesses some economic value as such in a region where true game birds are scarce, as in Porto Rico. It merits protection, therefore, during the breeding season, from March 1 until October 1, at least. Nest robbing is at all times a pernicious practice, and if taking eggs of coots be permitted, ducks' nests will inevitably suffer at the hands of men who do not care to distinguish between them.

[**CARIBBEAN COOT.** *Fulica caribæa* Ridgway.

GALLARETA.

The only record of the Caribbean coot is that of Cory (1892, p. 91), who assigns it to Porto Rico without comment or definite record. It is distinguished from the common coot by having a broad red frontal plate on the head. At present it can be considered only of doubtful occurrence.]

FLORIDA GALLINULE. *Gallinula galeata galeata* (Lichtenstein).

GALLARETA DE AGUA, YAGARETA, DAGARETA, GALLINAZA.

The Florida gallinule is resident in Porto Rico, though there is apparently some migration among individuals. It is found in quiet water near the mouths of large rivers where there are suitable growths of water plants for cover and in fresh-water marshes and sloughs. April and May appear to be the breeding months, as young about 5 days old were seen near Yabucoa May 8.

In the marshes and rivers these gallinules are seen frequently swimming across open stretches of water, or when encountered suddenly in rounding a bend fly up and away, singly or in pairs. If a female with her young is disturbed she will remain almost within reach, calling excitedly until the chicks are safe. Where gallinules are common they are heard cackling and calling on all sides and their notes are the dominant sounds of the marsh. Sometimes one will clamber up the reeds and balance near their tips, clucking excitedly, but usually once they are safe in the growth of water plants they can not be seen even a few feet away. The birds are somewhat pugnacious among themselves, especially during the breeding season, and may be seen darting at one another with open bills.

In the Laguna de Guanica the country people hunted for their eggs, examining every clump of grass or reeds and working the ground so systematically that it is a wonder any remain. The birds should be rigidly protected during the breeding season, as they are of some value as a game bird in a country where game is scarce.

Food.—Vegetable matter forms the main sustenance of this gallinule, as four stomachs taken in May contained 96.75 per cent, while only 3.25 per cent of animal matter was present. A single stomach taken in April held what appeared to be crustacean eggs to the amount of 95 per cent, but this may be exceptional. The other food taken by this bird was vegetable matter, mainly grass.

Bits of a true bug (lygæid) were found in one stomach and a small back swimmer (*Plea striola*) in another. Beetles of the water-scavenger family occurred in two stomachs, part of a weevil root-borer (*Diaprepes spengleri*) in another, and fragments of two small Hymenoptera in a third. One bird had eaten three snails (*Paludetrina coronata*) and two small bivalves (*Mytilopsis leucopheata*).

Grass and rootlets formed 90.75 per cent of the total contents, and seeds made up 6 per cent. Among those identified were knotweed (*Polygonum* sp.), many grass seeds (*Panicum* sp., *Paspalum virgatum schreberianum*), white-top (*Dichro-*

mena ciliata), fimbriatylis, purslane (*Portulaca oleracea*), pigweed (*Amaranthus* sp.), cadillo altea (*Triumfetta* sp.), and heliotrope (*Heliotropium indicum*).

A native living near some sloughs below Yabucoa charged these birds with destroying and eating the gonduros (*Cajanus cajan*) in her garden, but I heard no other complaint against them, and they may be considered harmless.

PURPLE GALLINULE. *Ionornis martinicus* (Linnaeus).

GALLARETA PLATANERA, GALLARETA MARTINIQUEÑA, GALLARETA, DAGARETA.

Gundlach (1878, p. 392) says that the purple gallinule was common in the seventies and damaged rice by eating the grain and breaking down the stalks. Taylor (1864, p. 171) also found it very abundant in suitable localities, and Sundevall (1869, p. 601) received seven specimens from Hjalmarson. Now, however, these gallinules are rare, and the only recent record available is that of Dr. C. W. Richmond (MS.), who saw one March 3, 1900, near Luquillo, walking about on some mangrove roots. Gundlach (loc. cit.) says that they build a nest like that of the Florida gallinule and lay from 6 to 10 eggs.

BLACK RAIL. *Creciscus jamaicensis* (Gmelin).

GALLARETILLA.

The black rail was first recorded for Porto Rico by Gundlach (1881, p. 401) from a bird taken by Stahl. The latter (1883, p. 63) considered it a rare visitant, and says (1887, p. 452) that it is found in swampy places and that young were taken. Dr. Richmond (MS.) examined a specimen from Porto Rico in the Stahl collection in San Juan, presumably the bird upon which the original records are based.

SORA, CAROLINA RAIL. *Porzana carolina* (Linnaeus).

GALLINUELA, GALLARETA DE CIENAGA, DAGARETILLA.

The sora is a winter visitant (from October until April) and is found in fresh-water swamps. I did not see the bird, but it is recorded by all the early naturalists. The most recent record is that of Dr. C. W. Richmond (MS.), who examined one taken at Luquillo March 5, 1900. The bird is known to many natives.

YELLOW-BELLIED RAIL. *Porzana flaviventris* (Boddaert).

GALLARETILLA.

The yellow-bellied rail is a rare resident, formerly rather common. May 26 in the marshes at the head of the Laguna de Guanica two were flushed from a growth of water plants bordering a small open pond about 2 feet deep. They got up quickly, flew high and swiftly, for rails, and then dropped and were lost in a dense growth of rushes. On July 23 two more, one an immature bird, flew up from the water plants fringing a small pond along the Bayamon River near Bayamon and dropped over into the denser growth. Gundlach (1878, p. 391) found them along the Rio Arecibo. These birds undoubtedly occur in other localities, but from their retiring habits escape notice. They appear to inhabit fresh-water marshes where the water is fairly deep, hiding in the dense vegetation. They are too small to be considered as game birds, even if their scarcity did not preclude hunting them systematically for sport.

CARIBBEAN CLAPPER RAIL. *Rallus longirostris caribæus* Ridgway.

POLLA DE LAGUNA, POLLA DE MANGLE, POLLA DE MANGLAR.

The Caribbean clapper rail is apparently not found except on salt water. It is a common species resident in the coastal region, occurring only in the wet mangrove swamps bordering the bays and brackish lagoons.

The bird is very shy and inhabits the densest swamps. On Culebra April was apparently the beginning of the breeding season and the rails were heard constantly. Near Mameyes one was seen slipping like a gray shadow between the roots at the edge of a lagoon.

In the region known as La Playita, near Salinas, clapper rails were abundant and by May 2 some had young a week old, while others were still laying. In the lower part of the swamps they were heard calling constantly and their tracks were seen everywhere in the soft mud. They fed through the more open parts of the mangroves here, sometimes darting across openings or even swimming across small pools of water. When caught in small isolated clumps of mangroves in deep water they frequently flew just above the water with a slow direct flight, rather than swim to safety. They ran swiftly, covering the ground with long strides, sometimes pausing when in the shelter of the mangroves to look back and see what startled them. One female followed by six or eight coal-black young was seen in a small opening, but at a slight noise all disappeared. One young bird taken was entirely black and had stocky legs and big feet.

Food.—Eleven stomachs of the clapper rail were examined and the food was found to be entirely animal matter. A small quantity of vegetable rubbish found in one stomach was without doubt taken accidentally and may be disregarded. Two stomachs were entirely empty, leaving nine available for study. Only one contained fish remains and the others, with the single exception of the small amount of vegetable matter noted, were filled with remains of crustaceans usually finely ground. The great mass of these were identified as fiddler crabs (*Uca pugnax rapax*) and they formed the entire contents of six of the stomachs examined and occurred in seven of the nine. Other crustacean remains, together with these crabs, form 94.45 per cent.

This bird is of value as a game bird and from its habits is capable of holding its own so long as the mangrove swamps remain. It should, however, be protected from March 1 to December 1, at least.

LIMPKIN, COURLAN. *Aramus vociferus* (Latham).

CARRAO, GUAREAO.

Although reported from many localities, the carrao, or limpkin, can be recorded certainly only from the north slopes of El Yunque above Rio Grande, the region between Adjuntas and Maricao, and the Hacienda Jobo west of Utuado. It is apparently unknown on the smaller islands and is now very rare on Porto Rico. Formerly more abundant, it was highly esteemed as a game bird. Gundlach (1878, p. 387) records it as common and nesting from the end of December through January, laying from three to five eggs. He describes its food as consisting of mollusks, earthworms, insects, crustaceans, and land shells.

In Porto Rico the limpkin inhabits dense wet forest growth in remote localities and occurs usually on steep slopes, frequently at some distance above the streams. It is said to be found in pairs, and when hunted the birds run rapidly and noiselessly before the sportsman, rarely flying, seeking the densest cover. Only in early morning do they come out into the more open forest. The natives are said to pursue them on foot through the wet growth. Soon the birds' feathers become too wet for flight, and in a short time, when tired out, they may be captured in the hand. The native name is given to the bird in imitation of its cry.

The main part of the food is said to be the common large land shells (*Pleurodonte carocalla*), and to some extent lizards.

The clearing of the forest has done much to lessen the numbers of this bird, while the mongoose without doubt takes its full share, living, as it does, upon the ground; so that the limpkin is no longer valuable as a game bird, though scattered individuals may survive for many years. Mr. Leop. B. Strube, of the Hacienda Jobo, stated that there were still at least a dozen pairs on his plantation living in a small tract of natural forest, and as they are protected they will survive. Mr. Strube kindly presented the Biological Survey with a specimen taken in June in that locality.

MEXICAN JACANA. *Jacana spinosa* (Linnæus).

GALLITO.

Gundlach (1878, p. 385) says that Blanco received a specimen of the Mexican jacana in the flesh from Trujillo. There are no other records, and the bird must be regarded as an accidental visitant.

OYSTER-CATCHER. *Hematopus palliatus* (Temminck).

CORACOLERO, OSTRERO.

The oyster-catcher is reported as occurring occasionally on the islands of Culebra and Culebrita. Gundlach (1878, p. 379) reports a specimen on the authority of Blanco, taken near San Juan, and Stahl (1887, p. 449) says that it was seen at the end of August, 1886. On the rocky beaches of Desecheo, June 13 to 15, three were seen and others reported by fishermen, to whom they are well known. From an economic standpoint this bird has no importance whatever, but is worthy of protection because of its harmlessness.

RUFIOUS-NAPED PLOVER. *Ochthodromus wilsonius rufinuchus* (Ridgway).

CORREDOR, FRAILECILLO CABEZON, PLAYERO, PLAYANTE.

Gundlach (1878a, p. 189) found the rufous-naped plover at Cabo Rojo and Arecibo in October and February and says (1878, p. 381) it is resident. Stahl (1883, p. 63) also considered it a resident species and says emphatically that it does not migrate. There is a specimen in the United States National Museum, taken February 11, 1899, on Culebra by Dr. J. D. Milligan. Bowditch (1902-3, p. 360) found these plovers on Vieques during November. Dr. Richmond secured specimens in the same locality on March 27, 1900. The bird is now rare, and none were seen during my work in this region.

PIPING PLOVER. *Ægialitis meloda* Ord.

PLAYERO, PLAYANTE, FRAILECILLO MELODICO.

Gundlach (1874, p. 314) saw a piping plover in the Blanco collection, taken near San Juan. Stahl (1883, p. 152) had two specimens (examined in 1900 by Dr. Richmond) from Porto Rico, and says (1887, p. 449) that the birds arrive the middle of August. The bird seems to be a rare migrant to the island.

SEMIPALMATED PLOVER. *Ægialitis semipalmata* (Bonaparte).

PLAYERO, PLAYANTE, FRAILECITO, FRAILECILLO CHICO.

The semipalmated plover is at present apparently rather a rare migrant. One was seen on the north coast of Vieques March 30, but was not secured. Gundlach (1878a, p. 189) records it as common in September at Mayagüez and as occurring in April, May, and June, while Sundevall (1869, p. 602) notes a specimen taken by Hjalmarson in winter. Stahl (1883, p. 152) had three specimens in his collection, one of which was examined in San Juan by Dr. Richmond (MS.), who also collected specimens March 5, 1900, at Luquillo, which were not preserved. Stahl (1887, p. 449) notes that they arrive the middle of August.

ANTILLEAN KILLDEER. *Oxyechus vociferus rubidus* Riley.
PLAYERO, PLAYANTE, PLUVIAL SABANERO, FRAILECILLO SABANERO.

The Antillean killdeer is a resident species, common locally in the coastal region. In July, after the breeding season, it goes inland along the larger streams as far as Utuado, Ciales, and other inland towns.

In February these killdeer seemed to be paired (Mameyes), and on March 23 on Vieques a female taken along a small stream contained an egg nearly ready for the shell. A young bird secured near Añasco June 7 had down feathers still clinging to the tips of the rectrices. During the breeding season the birds frequent mainly the dry open shores of lagoons near the coast, but the rest of the year wander a great deal. In the sandy region north of Manati they are very common and numbers frequent the citrus groves, apparently breeding there. In such localities the birds are well worthy of protection while nesting, because of their beneficial habits, and insectivorous birds in the orchards are few.

The birds are, as in the North, noisy and restless, and about the lagoons frequently alarm other waterfowl with their loud cries. During the breeding season their outcries are doubled, and in regions where they have nests or young they may be seen continually flying overhead, or running along on the ground, always with their loud notes, stopping to fall on their breasts with outspread fluttering wings or to simulate a brooding bird covering her eggs. After the breeding season many are found along the broad gravel bars of the larger streams.

Food.—Twenty stomachs of the killdeer taken in February, March, May, June, and July were examined, and showed 98.34 per cent animal matter and 1.66 per cent vegetable. Orthoptera, beetles, flies, and snails make up the bulk of the animal food, and the small percentage of vegetable matter is composed mainly of seeds, with a little rubbish.

Animal food.—The killdeer proves to be an important enemy of the mole cricket. It was found in 10 stomachs and forms 14.42 per cent of the food. Nymphs only appear to be eaten, as the bird can not break up the adults in order to swallow them, but this in no wise lessens the value of its services. Seven changas were found in one stomach, six in another, and several stomachs contained three each. Other Orthoptera amounted to 2.04 per cent, and were made up of miscellaneous fragments, among which were identified two small crickets (*Ellipes minuta*). Weevil remains (3.09 per cent) were recognized in four stomachs. The only one determined was a curculio (*Erodiscus* sp.). Other beetles make 29.17 per cent, the largest single item in the dietary of this bird. Water scavenger beetles (*Berosus* sp. and *Philhydrus* sp.) were found eight times, and a small dung beetle (*Atanius stercorator*) seven times. Darkling beetles (Tenebrionidæ) were taken by six birds, and though not of much importance economically, they are of interest as showing that in Porto Rico as in the southwestern United States there are a number of ground-haunting forms of this family. Only one genus (*Crypticus*) was identified. The striped flea beetle (*Systema basalis*), injurious to nearly all garden vegetables, was found twice, and a corn leaf-eating beetle (*Myochrous* sp.) four times. The habits of the latter species in Porto Rico are not known, but in the Southern States they damage young corn by eating the leaves. Another flea beetle (*Haltica* sp.) was found in one stomach. All of these leaf-eating beetles are more or less noxious and in many cases become very injurious. Only one ground beetle (*Selenophorus* sp.) was found, and this was the only beneficial insect taken.

Fly larvæ occurred in seven stomachs, and comprised 19.53 per cent of the contents. Ants form 5.59 per cent, and were found in ten stomachs. The fire ant

or brown ant (*Solenopsis geminata*) had been eaten by seven birds, one stomach containing 41, another 50, and another 83 individuals. This ant is known to be very injurious to young orange trees, so that the killdeer at once becomes of importance in the citrus groves. One broad-shouldered water strider (*Microvelia* sp.) and a single water boatman (*Corixa* sp.) were found. One stomach contained 12 caterpillars and another an ichneumon fly. These miscellaneous items form 1.56 per cent.

Dragon flies occur in two stomachs taken in July, and form 3.92 per cent of the total. Mollusks figure as 19.02 per cent, and among them three genera were identified (*Truncatella*, *Planorbis*, and *Paludestrina*). One stomach contained a few fish remains.

Vegetable food.—Though amounting to only 1.66 per cent of the total, vegetable matter was found in nine stomachs; in only two was there material that could be classed as rubbish. Each of the other seven held small seeds, among which were identified guinea grass (*Panicum* sp.), crab grass (*Syntherisma sanguinalis*), white-top (*Dichromena ciliata*), pigweed (*Amaranthus* sp.), purslane (*Portulaca oleracea*), knotweed (*Polygonum* sp.), plantain (*Plantago* sp.), croton (*Croton* sp.), and several seeds of composite plants. The large share of these are weed seeds growing abundantly in the haunts of this killdeer.

Although small, the Antillean killdeer might be considered a game bird, but its food habits warrant giving it full protection and encouragement, as its services to the agriculturist are too valuable to be lost. It is especially useful in cultivated fields and orchards. Analysis of its food shows that it is entirely beneficial, and from its habits it can perform services not rendered by other birds.

GOLDEN PLOVER. *Charadrius dominicus dominicus* (Müller).

PLAYERO, CHORLITO, PLUVIAL.

The golden plover is apparently a rare migrant through Porto Rico. Sundevall (1869, p. 602) speaks of two specimens sent him by Hjalmarson. Gundlach (1878a, p. 189) secured specimens near Arecibo in November, and Stahl (1883, p. 152) had two in his collection. One bird was seen feeding along the beach near the mouth of the Rio Mameyes February 16, but was not secured. There are no other records for this bird.

BLACK-BELLIED PLOVER. *Squatarola squatarola* (Linnæus).

PLUVIAL, PLUVIAL GRANDE.

Gundlach (1878a, p. 188) secured specimens of the black-bellied plover around San Juan Bay, and Stahl (1883, p. 152) had two specimens from Porto Rico in his collection. There are no other actual records for the bird, and it must be regarded as a rare migrant.

RUDDY TURNSTONE. *Arenaria interpres morinella* (Linnæus).

PLAYERO TURCO, PUTILLA TURCA.

Gundlach (1878, p. 379) records the arrival of the ruddy turnstone in September and says it remains until May. He found the species (1878a, p. 188) at Mayagüez, Cabo Rojo, Quebradillas, and Vega Baja. It is a winter visitant apparently tolerably common. On February 15 a small flock was seen by the writer feeding along the mud flats on Punto Miquillo north of Mameyes, and the same flock was observed again on the 21st. The birds kept close together on the ground, and when startled got up with a loud whistled note, flying in a compact flock. They were well known to fishermen and charcoal burners near Mameyes, and were said to occur regularly. On April 15 three or four were seen on Culebrita Island. This species occurs only where there are mud flats

suitable for it to feed upon, and only in the immediate neighborhood of the coast on either brackish or salt water.

Food.—Five stomachs of the turnstone taken in February and April were examined and were found to contain animal matter only. One contained a few small fish scales, but small crustaceans made up the bulk of the food. The greater part of these were amphipods (*Orchestia* sp.), while a smaller number of isopods (*Excirolana mayana*) were eaten. No other groups could be identified. Nothing is eaten that is beneficial or injurious to man.

ESKIMO CURLEW. *Numenius borealis* (J. R. Forster).

CURLIS, CHORLO.

The only record for the Eskimo curlew is that of Gundlach (1878a, p. 188), who mentions a single specimen taken near San Juan by Don Tomas Blanco.

HUDSONIAN CURLEW. *Numenius hudsonicus* Latham.

CURLIS, BARGA, CHORLO.

Gundlach (1878a, p. 187) saw the Hudsonian curlew in the collection of Blanco in San Juan, and (1878, p. 367) says that he once found this bird along the river at Punta Arenas south of Mayagüez. Stahl (1883, p. 150) recorded two specimens in his collection and these were seen in San Juan in 1900 by Richmond (MS.).

SPOTTED SANDPIPER. *Actitis macularia* (Linnæus).

PUTILLA, PLAYERO, PUTILLA MANCHADA, ZARAPICO MOSQUEADO.

A common winter visitant from July to May, the spotted sandpiper is the most abundant and widely distributed shorebird in the island.

It frequents the mangrove swamps, borders of lagoons, margins of all the streams, and occasionally the sandy beaches. During the winter season it follows inland along the small streams and occurs throughout the island. The first fall bird taken (at Manati July 9) was an adult, and none but adults were seen until July 27, when immature birds were common along the Rio de la Plata above Comerio. The last bird in the spring was seen near Patillas May 13. Thus the bird is present in the island 11 months of the year, though it does not nest there.

Food.—Nine stomachs of the spotted sandpiper representing the months from December to April, and July and August were examined. Animal matter comprised 99.78 per cent of the food, leaving only 0.22 per cent for vegetable matter, which consisted of rubbish found in two stomachs. The greater share of the food is made up of crustaceans, with smaller amounts of mole crickets, bugs, and beetles. Though mole crickets (*Scapteriscus didactylus*) were found in but two stomachs, they form 10.78 per cent of the total food. All were nymphs, as this bird is not able to break up the adults with its slender bill; four were in one stomach and two in another. Nearly all the birds collected were taken near mangrove swamps and along beaches, and it is very probable that along inland streams, flowing through cultivated fields, spotted sandpipers would pick up many more changas than is here indicated.

One bird had eaten a tiger beetle, 13 adult water scavenger beetles (*Berosus* sp.), and 4 hydrophilid larvæ, amounting to 3.89 per cent of the total. Aquatic bugs made 4.11 per cent of the whole; seven broad-shouldered water striders (*Mesovelia* sp., and *Microvelia* sp.), two water boatmen (*Corixa* sp.), and three back swimmers (*Plea* sp. and *Notonecta* sp.) were found in one stomach. Crustaceans aggregated 80.12 per cent and were made up of small amphipods and fiddler crabs (*Uca pugnax rapax*). Another small crab (*Sesarma* (*Holometopus*) *roberti*) and an isopod (*Excirolana mayana*) also were identified. Ants

in one stomach and bits of an earwig in another form miscellaneous matter amounting to 0.88 per cent.

From the foregoing the spotted sandpiper is a beneficial species and should not be molested. Only one item can be charged against it, a single tiger beetle, and that is too small to be of value. Fortunately the bird is common and, though only a migrant, is present for the greater part of the year. Thus it can be of great value in aiding in the war on the mole cricket.

UPLAND PLOVER. *Bartramia longicauda* (Bechstein).

GANGA.

The only known record for the upland plover is that of Stahl, who (Gundlach, 1881, p. 401) secured one some time between 1878 and 1881.

WILLET. *Catoptrophorus semipalmatus semipalmatus* (Gmelin).

CHOBLO.

The willet was found by Stahl around San Juan Bay and by Gundlach (1878a, p. 188) at El Boqueron near Cabo Rojo. The latter writer says that these birds occurred on marshy shores and that he believed they nested on the island. Naturalists visiting the island more recently have failed to record them.

SOLITARY SANDPIPER. *Helodromas solitarius solitarius* (Wilson).

PUTILLA, SOLITARIO, ZARAPICO SOLITARIO.

The solitary sandpiper is a tolerably common winter visitant, apparently more abundant on the western half of the island. The first bird for the fall was an immature specimen taken along the Rio de la Plata above Comerio July 29, and by the last of August the species was common around Cabo Rojo. At Humacao a few birds were noted along the Rio Humacao the first week in September, but I saw none in the eastern part of the island in the spring. These sandpipers are found singly, scattered about pools of water left in the lowlands by the heavy rains, in wet, newly plowed fields, on mud flats, in the lagoons of the coastal region, or along streams. Tame and unsuspicious, they walk with a quick, tilting motion of the body, and when flushed fly rapidly, with a quick note—*pees wees*.

Sundevall (1869, p. 602) received a winter specimen in the collection of Hjalmarson; Gundlach (1878, p. 372) records them from the second half of September to April; and Bowdish (1902-3, p. 360) says that they are often seen in fall and winter.

Food.—Two stomachs taken in July and August contained nothing but animal matter. More than half the contents consisted of dragon-fly nymphs and a large part of the remainder of water-scavenger beetles (*Berosus* sp. and others) and their larvæ. One bird had eaten a water boatman (*Corixa* sp.). Though the predacious dragon flies taken by these two weigh strongly against them, it may be found on examining more material that the birds consume injurious insects enough to counterbalance this. The birds should not hastily be condemned, as there is no reason to suppose that their food differs greatly from that of the spotted sandpiper. It may also be found that, like that species, they consume numbers of the nymphs of the mole cricket.

LESSER YELLOW-LEGS. *Totanus flavipes* (Gmelin).

CHOBLO, CABALLERO, PATIAMARILLO.

The lesser yellow-legs is recorded as a winter visitant from September to April (Gundlach, 1878, p. 371), but seems to be more common during fall migration. Dr. Richmond (MS.) noted the species on Vieques, March 25, 1900, and this is the only known recent spring record. Stahl (1887, p. 449) says that in 1886 the first were seen on August 9, somewhat earlier than in previous years.

I found them only near Cabo Rojo from August 24 to 31, when fall migration was apparently at its height. The birds fed along the overflowed borders of lagoons and also in moist newly plowed fields in the lowlands. Many were seen in flight following the trend of the coast southward.

Food.—Four stomachs examined, all taken at Cabo Rojo the last of August, contained nothing but animal matter. Water boatmen (*Corixa* sp.) found in each of the four make 57.5 per cent, and two stomachs contained nothing else. Crustacean remains, among which were several crabs (*Sesarma* (*Holometopus*) *roberti*), were identified in two stomachs, and make the remainder, 42.5 per cent. Apparently this species is neutral as regards agricultural interests.

GREATER YELLOW-LEGS. *Totanus melanoleucus* (Gmelin).

PLAYERO, CABALLERO CHILLON, ZARAPICO BLANQUINEGRO.

Apparently a migrant in spring and fall in Porto Rico, the greater yellow-legs may occasionally spend the winter there around some of the more inaccessible lagoons. Three were noted near Salinas May 2 and one was taken. A single individual was seen May 26 at the Laguna de Guanica, and on August 26 three or four were feeding on mud flats at Porto Real, near Cabo Rojo. The species is recorded by Sundevall (1869, p. 602) and Gundlach (1878, p. 370). Stahl (1887, p. 449) found them as early as August 9, 1886.

Food.—The stomach of the single bird taken was nearly full of finely ground fragments of small crustaceans. The only other items were the maxillæ of an aquatic larval insect. Nothing of economic importance was taken.

MARBLED GODWIT. *Limosa fedoa* (Linnæus).

CHORLO, BARGA.

Gundlach (1878, p. 368) records the marbled godwit from Boqueron below Cabo Rojo, where he found a single bird. There are no other certain records.

SANDERLING. *Calidris leucophæa* (Pallas).

ARENEBO, PUTILLA.

The sanderling is apparently a rare migrant in Porto Rico. The first record is that of Gundlach (1878, p. 376), who notes a male taken at Bayamon by Stahl. The latter (1883, p. 151) says that he had two specimens in his collection and adds (1887, p. 450) that the species lingers late in spring. Nothing further has been found regarding its occurrence.

SEMIPALMATED SANDPIPER. *Ereunetes pusillus* (Linnæus).

PUTILLA, PUTILLITA DIMINUTA, ZARAPICO GRACIOSO.

The semipalmated sandpiper is a tolerably common winter visitant. From August 24 to 31 individuals were common in the coastal region at Cabo Rojo about the shallow lagoons. Several times they were seen singly or in small flocks feeding in newly plowed fields, where the soil was soft from the heavy rains, climbing over clods and furrows, or gathering about small pools of standing water. Bowdish took a specimen on Mona Island August 11, 1901, and Gundlach (1878, p. 374) records it as a winter visitant. Sundevall (1869, p. 602) notes four specimens received from Hjalmarson. Stahl (1887, p. 449) says that they arrived at the end of August, 1886, and (loc. cit., p. 452) that a few individuals remain throughout the summer.

Food.—Six stomachs taken at Cabo Rojo in August contained 99.16 per cent of animal matter and 0.84 per cent of vegetable matter. Beetles, bugs, fly pupæ, and small mollusks form the bulk of the food. Small water scavenger beetles (Hydrophilidæ) were found in four stomachs and amount to 27 per cent. Two ground beetles (*Bembidium* sp.) amount to 5 per cent, and miscellaneous

beetles to 3.34 per cent. One bird had eaten nothing but four back swimmers (*Notonecta* sp.), and these made 16.66 per cent. Fly pupæ figure largely in two stomachs, forming 21.66 per cent of the total, and snails (*Planorbis* sp.) 13 per cent, while miscellaneous animal matter amounts to 12.50 per cent. The small quantity of vegetable matter present was rubbish. The numbers of Diptera eaten speak well for this sandpiper.

LEAST SANDPIPER. *Pisobia minutilla* (Vieillot).

PUTILLA, PUTILLA MENUDA, SARAPICO PEQUEÑO.

Gundlach (1878, p. 376) records the least sandpiper as a winter visitant. It is still common during migration. Stahl (1887, p. 449) says that the birds arrived from the north at the end of August in 1886, and that a few individuals remained through the summer. Bowdish (1902-3, p. 360) notes the first arrivals for Porto Rico September 23, 1900, and September 4, 1901. He also found them common on Mona Island August 9 to 21, 1901. I saw one at the Laguna de Guanica May 26, and August 28 one at Joyuda, near Cabo Rojo. Further observations may show that they are more common in other localities.

Food.—The stomach of the single bird taken contained the heads of more than 100 minute fly larvæ (75 per cent) and fragments of small beetles (*Heterocerus* sp.) (25 per cent).

WHITE-RUMPED SANDPIPER. *Pisobia fuscicollis* (Vieillot).

PUTILLA.

The white-rumped sandpiper is a rare migrant and possibly a winter visitant to Porto Rico. Bowdish (1902-3, p. 360) took one near Mayagüez October 2, 1900, the first record for the island. April 15 I saw two on the north shore of Culebrita Island. The species should occur on mud flats bordering lagoons and in similar localities.

PECTORAL SANDPIPER. *Pisobia maculata* (Vieillot).

PUTILLA, PUTILLA PINTA, SARAPICO MANCHADO.

Gundlach (1878, p. 375) records the pectoral sandpiper as a winter visitant from September to April, but it probably occurs more commonly during migration. Stahl (1887, p. 452) says that it lingers late in spring and that a few individuals are found through the summer. Bowdish (1902-3, p. 359) secured specimens September 26, 1900, and October 2 near Aguadilla. I saw a flock of about a dozen around a little tidal pool near Guayanilla August 24.

STILT SANDPIPER. *Micropalama himantopus* (Bonaparte).

PUTILLA, SARAPICO ZANCUDO.

On August 28 a pair of stilt sandpipers came driving swiftly down the coast at Joyuda, near Cabo Rojo, and one was taken. They are winter visitants, apparently rather rare, and are to be looked for on mud flats bordering lagoons and about shallow pools of water with muddy shores. Gundlach (1878, p. 373) says that they arrive in September. Sundevall (1869, p. 602) received three specimens from Hjalmarson. Stahl (1883, p. 151) had one specimen in his collection. The stomach of one bird, taken about 11 in the morning, contained gravel alone, which would indicate that this individual was a migrant and had come a long distance.

WILSON'S SNIPE. *Gallinago delicata* (Ord).

BECAICINA.

According to Gundlach (1878, p. 368) Wilson's snipe is a winter visitant, occurring from September until spring. December 19, 1911, a dozen were seen about a pool in a low field near Rio Piedras and one was taken; another was

flushed at the edge of a mangrove swamp December 22. The fact that these snipe occur on the island in the winter months is unknown to most sportsmen, but apparently they are to be found about fresh-water marshes and swamps in fair numbers during early winter.

Food.—The stomach of one bird contained bits of a water boatman (*Corixa* sp.), remains of two larval water scavenger beetles, and fragments of an ant, all of which amounted to 30 per cent of the bulk. Mole cricket remains (*Scapteriscus didactylus*), an interesting find in the stomach of this bird, amounted to 10 per cent. Vegetable matter (60 per cent) was composed mainly of bits of grass, wood, etc., while three seeds of guinea grass (*Panicum* sp.) and one of sedge (*Carex* sp.) were identified. Examination of a large number of stomachs of this snipe might show that it is an important enemy of the changa.

BLACK-NECKED STILT. *Himantopus mexicanus* (Müller).

VIUDA, PLAYANTE, YEGÜETE, ZANCUDO.

The black-necked stilt is a resident species formerly common everywhere in the lagoons. Gundlach (1878, p. 377) records it from Puerto Real, Cabo Rojo, Boqueron, and the Rio Arecibo. At present it is found commonly only in the extensive lagoons and swamps between Salinas and Guayama, at the Laguna de Guanica and around Boqueron, and only stragglers occur in other localities. In March, 1900, the birds were reported as occasional on Vieques (Richmond MS.). When feeding they wade among the plants in water almost to their bodies, swimming when beyond their depth, or else pick their way along the muddy shores of the lagoons, gleaning as they go. The breeding season extends apparently from the last of April to the first of June, and at that time the birds are very noisy. Long before the marshes are reached their notes may be heard, and as one approaches stilts come flying out rather slowly, the long legs stretched out behind, calling *kek kek kek* loudly. As they pass overhead they circle rapidly, but are easily killed and are too often a mark for the sportsman. That the male assists in incubation is evidenced by two prominent incubation patches, one on either side of the breast, found in birds secured in April and May.

Food.—Two stomachs of the stilt were examined and found to contain animal matter only. Water boatmen (*Corixa* sp.) were present in large numbers and form more than half the bulk. Small fish scales amount to 40 per cent, and the remainder consists of miscellaneous matter. Though many fish are eaten, the birds would be harmful only in the immediate vicinity of a fish hatchery.

LAUGHING GULL. *Larus atricilla* Linnaeus.

GAVIOTA, PALOMITA, FORASTERA, GALLEGO, GAVIOTA BOBA.

The laughing gull is a species fairly common along the seacoast of Porto Rico, Vieques, and Culebra. Bowdish (MS.) found them common around Mona August 9 to 21, 1901. In San Juan Harbor only an occasional bird was seen during the winter months, but by July there were numbers. On Culebra they were common after April 15 in the harbor, and I heard and saw them frequently. Around Desecheo the middle of June there were about 30, though none seemed to be breeding. They were continually passing up and down the coast, calling and scolding whenever I was in sight. At times they came around my camp to investigate the refuse, but otherwise were rather wild. Their flight is strong and direct.

Food.—Fish remains comprised 70 per cent of the contents of two stomachs and in one was found a crab (*Plagusia depressa*). Gulls are always largely

scavengers. Bowdish saw two feeding on the body of a booby which he had skinned and thrown into the water.

NODDY. *Anous stolidus stolidus* (Linnæus).

GAVIOTA, CERVERA.

The noddy was an abundant species on Desecheo Island the middle of June and was not noted except in that vicinity. About 2,000 of them were already on the island, while many had not yet come in to nest. The birds were found on the rough limestone ledges in parties of from half a dozen to 500, and their nests, mere collections of small flat stones, a twig or two, and perhaps a feather, were in hollows in the rock. Four eggs collected showed incubation of about five days and one was fresh. The females were apparently doing most of the incubating, with the males standing guard, but the latter must have occupied the nests part of the time, as all showed bare incubation patches on the breast.

Bowdish (1902-3, p. 358) notes them as common on the coasts of the main island and abundant on Mona and Desecheo. The nesting dates apparently vary somewhat from year to year, as he found well-grown young June 24, 1900.

Food.—Three stomachs of the noddy taken on Desecheo were examined and one was found to be entirely empty. Another contained the horny beaked jaws of a squid, and the third one medium-sized and two small fish. Definite statements concerning the food of this bird can not be made from this small amount of material, but undoubtedly fish form a large part of it and various marine animals the rest.

BLACK TERN. *Hydrochelidon nigra surinamensis* (Gmelin).

GAVIOTA, GAVIOTA NEGRA.

The only authentic record of the black tern is that of Gundlach (1878a, p. 191), who saw a specimen in the collection of Blanco in San Juan. It must be considered of casual occurrence in this region.

BRIDLED TERN. *Sterna anæthæta* Scopoli.

GAVIOTA.

The handsome bridled tern was common on the rough, eroded limestone rocks strewing the lower portions of the north and west coasts of Desecheo Island. Bowdish (1902-3, p. 357) found them common on Desecheo and Mona and also records them from the coast of the main island, but Gundlach did not find them. As nearly as could be estimated there were about 1,500 of them on Desecheo. June 15 was apparently the beginning of the breeding season, as, although two eggs taken were far along in incubation, many of the birds had not laid.

Food.—Of five stomachs examined one was entirely empty. Fish remains were present in all the other stomachs and amounted to 70 per cent. One species was identified as a filefish (*Alutera* sp.). Mollusks (25 per cent) were represented by a gastropod and a cephalopod (*Spirula australis*), the latter one of the few of that order bearing a shell that exist to-day. Miscellaneous matter (5 per cent) consisted of a moth and a small echinoderm. Fish and marine mollusks form the large bulk of the food, and under present conditions the birds are to be considered harmless, as the fish eaten are not of economic importance.

SOOTY TERN. *Sterna fuscata* Linnæus.

GAVIOTA, GAVIOTA OSCURA.

Gundlach (1878, p. 414) found sooty terns common on the north coast of Porto Rico and in July noted them at Mayagüez, while Stahl (1887, p. 453)

says that he once shot a pair on the south coast of the island in June. Bowdish (1902-3, p. 357) found them common August 9 to 21, 1901, on Mona, which is undoubtedly one of their breeding places. I saw one with some common terns in the bay at Joyuda, near Cabo Rojo, August 28, and another with a flock of laughing gulls near Rincon September 2. Two were seen at sea about 200 miles north of Porto Rico September 12.

LEAST TERN. *Sterna antillarum* (Lesson).

GAVIOTA, GAVIOTA ANTILLANA.

Gundlach (1878, p. 412) says that the least tern was found by Blanco near San Juan, and by Stahl at the mouth of the River Toa (Rio de la Plata); and Stahl (1887, p. 453) says that they come in September. The latest record for them is that of Bowdish, who (1902-3, p. 357) saw a pair off Cabo Rojo Light-house August 22, 1901.

ROSEATE TERN. *Sterna dougalli* Montagu.

GAVIOTA.

On June 16 a small flock of roseate terns was seen feeding over the water and then resting in a close flock on the surface, between Desecheo and Porto Rico. July 8 a few were noted along the curiously eroded limestone ledges forming the shore line north of Manati. They darted about over the bare rocks above the ocean, harshly calling *cack, cack*. One of them, a female in rather worn plumage, was taken, and from their actions they were breeding, though no nests were found. At Joyuda near Cabo Rojo on August 28 five or six were feeding with a flock of common terns and resting with them on rocks in the water. Gundlach (1874, p. 314) doubtfully records the roseate tern as seen in Blanco's collection, and Cory (1892, p. 82) lists it from Porto Rico without comment. If *Sterna d. gracilis* Gould is retained as a valid subspecies, then both varieties are represented in the collection from Porto Rico, as the bill of a fall bird taken at Joyuda is entirely black, while in the case of a female taken near Manati on July 8 the base of the bill is slightly reddish. It is felt, however, that more material is needed to settle this question definitely.

The two stomachs examined contained only fish remains. No other data concerning their food are available.

ARCTIC TERN. *Sterna paradisæa* Brünnich.

GAVIOTA, GAVIOTA DEL PARAISO.

Gundlach (1878a, p. 163) saw the Arctic tern in the collection of Blanco, taken near San Juan. According to Stahl (1883, p. 154), who had three specimens in his collection, they arrive in September (1887, p. 453). There are no other specimens on record.

COMMON TERN. *Sterna hirundo* Linnæus.

GAVIOTA, PALOMITA.

The last of August the common tern was fairly numerous along the coast at Porto Ferro and Joyuda near Cabo Rojo. This is apparently the first record for Porto Rico, though the winter range of the bird is given as from Florida to Brazil.¹ On August 28 these terns were following a school of mackerel that was driving up and down the shallow water behind the reefs at Joyuda. The birds dived down excitedly when the minnows were driven up, and when satisfied gathered in a close flock on rocks standing in the water. Two were collected.

¹ A. O. U. Check List North Amer. Birds, 3d ed., 1910, p. 44.

Food.—The two stomachs examined contained well-digested remains of minnows. One bird had eaten 12 or more and the other 6. These fish are not of economic importance.

CABOT'S TERN. *Sterna sandvicensis acuflavida* Cabot.
GAVIOTA, GAVIOTA DE PICO AGUDO.

Gundlach (1878, p. 411) found Cabot's tern common along the coast of Porto Rico, and secured a specimen at Mayagüez (1878a, p. 191). Stahl (1883, p. 154) had two specimens in his collection and remarks (1887, p. 453) that it is found throughout the year. It has not recently been seen here by naturalists.

ROYAL TERN. *Sterna maxima* Boddaert.
GAVIOTA, GAVIOTA REGIA, CHIRRE.

Tolerably common along the coasts of Porto Rico, Vieques, and Culebra, the royal tern is frequently seen in San Juan Harbor, usually alone but sometimes in company with laughing gulls. At Mameyes in February there were a few about Punta Picua, where they perch on posts standing in the water, always facing the wind. Occasionally one would swoop down and capture a minnow or circle around with harsh cries, but always returned to the same perch. Their occurrence here was not regular and the birds were evidently wanderers.

Food.—The three stomachs examined contained only fish, which without doubt form the greater part of their food. One parrot fish (*Sparisoma* sp.) was recognized, but the others were too well digested for identification. From observation the royal tern seems to be almost entirely piscivorous. Examination of more stomachs will doubtless corroborate this.

RUDDY QUAIL-DOVE. *Geotrygon montana* (Linnæus).
PERDIZ, PERDIZ DE MONTE, BOYERO.

The ruddy quail-dove is a rather rare resident species except in a few localities where protected by dense cover or in regions high in the mountains. Sometimes they are found in coffee plantations, but usually occur in areas of second growth on steep hillsides. The birds walk rapidly away before an intruder, with nodding heads, or else crouch down and hide, and in the dim light it is difficult to make them out. When frightened they fly with a loud fluttering, and after a few feet set the wings to sail off noiselessly. The mongoose, the greatest enemy of this bird, is abundant in the lowlands, but has not yet penetrated far into the interior. Apparently it has exterminated the quail-doves in the coastal region, as none were seen save near Manati.

The breeding season appears to begin the first of March, and the quail-doves seem to have but one brood a season. The natives say that they nest on the ground. Males during this period have a low resonant note, coming apparently from a distance, but finally resolving itself into a deep *coo-oo-oo*, with a peculiar undertone, as of the humming of the wind across the end of a gun barrel, a very striking sound, and one difficult to locate.

Food.—Five stomachs of the ruddy quail-dove were examined and found to contain vegetable matter alone, save that one bird had eaten an ant, taken probably by accident. During the orange season the birds feed largely on seeds of sweet oranges (chinas), and these were found in four stomachs. One bird had taken 17 seeds and another 13, while others contained smaller quantities. Field observation showed that these seeds were taken from decayed fruit lying under the trees. The fallen oranges were pecked open when they became soft from lying on the moist earth, the birds going straight to the centers and picking out the seeds, so that rotting oranges with neat round holes in them were common in the haunts of the perdiz. The soft bill of this dove would

preclude attacks on sound oranges. Hard ivorylike grass seeds (*Olyra latifolia*) were in two stomachs and pits of the moral (*Cordia* sp.) in two. One bird had eaten seeds of a spurge (*Chamaesyce* sp.), and other undetermined seeds belonging to the madder, myrtle, and spurge families were found. Leaves occurred in four stomachs and in one made a large part of the bulk.

Near Manati the birds fed on the fallen fruit of the manchineel (*Hippomane manchinella*), which to human beings is very poisonous. This was the only locality in which the birds were observed in trees.

The quail-dove may be considered a game bird, and should be given the same open season as the larger pigeons. In its food habits it is harmless and does a certain amount of good by eating harmful seeds.

KEY WEST QUAIL-DOVE. *Geotrygon chrysia* Salvadori.

PERDIZ MARTINIQUEÑA, BARBEQUEJO.

Taylor (1864, p. 171) says that the Key West quail-dove is not uncommon in Porto Rico, and Gundlach (1878, p. 347) records a specimen in the collection of Blanco and a drawing in the album of Bello. Stahl (1883, p. 148) had a male in his collection taken on the island. Bowdish (MS.) says that they were found on Mona from August 9 to 21, 1901, but he did not preserve specimens. A perdiz, possibly of this species, was described to me near Palo Seco, but I did not meet with it.

TEMMINCK'S QUAIL-DOVE. *Geotrygon mystacea* (Temminck and Knip).

PERDIZ.

A specimen in the National Museum, collected on Culebra Island February 9, 1899, by A. B. Baker, of the Fish Commission, is the only record of Temminck's quail-dove for this region (Riley, 1903, p. 14). None were found during my stay on Culebra, and it may be that the bird no longer occurs there. It has been previously recorded in St. Croix.

PORTO RICAN GROUND DOVE. *Chamepelia passerina trochila* Bonaparte.

ROLA, ROLITA, TORTOLITA.

The ground dove is a common resident species on all the islands visited, except Desecheo, being most abundant on Culebra. In Porto Rico it is rarely found above 500 feet altitude, but in following inland along the courses of streams it occasionally ranges up to 1,200 feet, as at Cayey and Lares. The birds occur on stony hillsides, in plowed fields, brush-covered pastures, and open country in general. They walk about quickly, with long steps and rapidly nodding heads, picking up seeds, bits of gravel, etc., as they go. Before an intruder they walk rapidly away, raising the tail nervously, or after crouching to the ground rise with a sudden flutter of wings and dart swiftly away, exposing the red undersurface of the remiges. The birds are found in pairs, or occasionally, before or after the breeding season, in small flocks. After flying a short distance they drop to the ground or perch in rather open trees, sitting close together. When alarmed they sidle quickly along the limbs, hiding behind them, or suddenly take flight. The males utter a loud note, *coo-coo-coo-coo*, when perched in the trees, and during summer these calls are answered from every side. The males also have a habit of sailing out in short circles, with wings stiffly spread, giving them an odd kitelike appearance.

The breeding season probably extends from the first of March to the last of August, though on Culebra the birds remained in flocks until the 10th of April before pairing. Nests on Vieques were large, deeply cup shaped, and contained much material, while Porto Rican nests were slight and flimsy, so that in many cases the eggs could be seen from beneath. Two eggs, white in color, form a

set, and at least two broods are reared in a season. While the females were incubating the males fed together, often in the yautia or cane fields. When caring for their young the females feed in the early morning, filling the crop with seeds, and then about 9 o'clock fly in to water, usually following well-defined routes. After drinking they perch quietly in the trees, and in about 30 minutes the "pigeons milk" forms as a thick curd, beginning in the lower portion of the crop. After June flocks of a dozen or more young gathered by themselves were common. They are said to have nested formerly on the ground, but now they build almost entirely in trees to escape the mongoose.

This species is one of the few found in cane fields, and it occurs regularly, even when the cane is well grown. These doves are very timid and show great fear of sparrow hawks, sometimes refusing to fly when they are in the neighborhood. During the breeding season the males were found in early morning feeding in the cane fields or else cooing from the hills, while the females were above on the hillsides. When there was a heavy dew the birds were inactive until 10 or 11 o'clock.

Food.—Seventy-two stomachs of the ground dove were examined and the food was found to be almost entirely vegetable. Animal matter, though present in 10 stomachs, amounted to only 0.25 per cent and may be considered accidental. Fragments of ants occurred in eight, while in the other two were spherical shining scale insects known as ground pearls (*Margarodes formicarum*). These are sometimes found loose in the soil, and from their appearance might be picked up as gravel to aid digestion.

The belief common in some localities that these doves consume many insects is not borne out by stomach examination. Like others of the pigeon family having similar habits, ground doves are almost entirely granivorous. As an instance of the unreliability of unverified field observations, I saw a bird on Vieques Island March 30 hopping rapidly about in the small terminal twigs of a muñeco tree, apparently in pursuit of insects. After watching it for a minute I collected it, and found to my surprise that it was a ground dove, and, on examining the stomach and crop in the laboratory, found seeds only and not a trace of animal matter.

Practically all the food, or, to be exact, 99.75 per cent of it, is composed of seeds. These are picked up usually in cultivated fields, the borders of roadways, trails, and other open localities. Weed seeds, as the term is commonly applied, form about one-fourth of this mass, though undoubtedly many classed here as miscellaneous should come under this head. Purslane, lamb's-quarters, various other seeds of the goosefoot family, amaranth, caltrop, sparges, and mallows are most commonly eaten, all of them noxious to the agriculturist. Grass and sedge seeds form another great class, amounting to about one-third of the whole. Crab grass and wire grass were taken frequently, and several species of panic grass and sedges form the bulk of the remainder.

Wild fruits, figs, and species of *Rubus* amount to only 3.4 per cent, while no grain or cultivated vegetable was found. The remainder consists of a mass of miscellaneous seeds, euphorbias, wild legumes, and seeds of various shrubs abounding in the localities frequented by this dove. As many as 16 varieties were identified in a single bird, counting the contents of crop and gizzard, and sometimes there were large numbers of a single species. One bird had eaten 9,600 seeds of purslane and another more than 5,000. In one stomach 2,400 Egyptian grass seeds were found and in another 1,450 of the amaranth. Other species were present in considerable numbers in each case.

Absolutely no harm is done to man or his interests by the ground dove, but, on the contrary, a certain amount of good is accomplished in the destruction of

pernicious weeds. Although many ground doves are killed by sportsmen, the species is too small to be considered a game bird, and because of its beneficial habits it should be protected throughout the year.

Following is a list of seeds identified in the stomachs of the ground dove, together with the number of stomachs in which found:

Many-seeded paspalum (<i>Paspalum mil-</i> <i>legrama</i>)-----	1	Carpet weed (<i>Mollugo verticillata</i>)---	1
Other paspalums (<i>Paspalum</i> sp.)-----	7	Verdolaguilla (<i>Talinum paniculatum</i>)_	1
Crab grass (<i>Syntherisma sanguinalis</i>) -	8	Verdolaga (<i>Portulaca oleracea</i>)-----	37
Panic grass (<i>Panicum fasciculatum</i>)_	29	Fresa (<i>Rubus</i> sp.)-----	1
Panic grass (<i>Panicum utowanæum</i>)----	1	Vetch (<i>Vicia</i> sp.)-----	18
Other millets (<i>Panicum</i> sp.)-----	29	Wild bean (<i>Phaseolus lathyroides</i>)----	2
Broad-leaved olyra (<i>Olyra latifolia</i>)--	1	Vinagrillo (<i>Oxalis</i> sp.)-----	3
Rush grass (<i>Sporobolus indicus</i>)-----	1	Caltrop (<i>Kallstræmia maxima</i>)-----	19
Wire grass (<i>Eleusine indica</i>)-----	30	Euphorbia (<i>Euphorbiaceæ</i> sp.)-----	14
Egyptian grass (<i>Dactyloctenium</i> <i>egypticum</i>)-----	12	Spurge (<i>Chamæsyce</i> sp.)-----	7
<i>Ichnanthus</i> (<i>Ichnanthus pallens</i>)-----	1	Jatropha (<i>Jatropha</i> sp.)-----	3
Fimbristylis (<i>Fimbristylis</i> sp.)-----	2	Croton (<i>Croton</i> sp.)-----	5
Whitetop (<i>Dichromena ciliata</i>)-----	3	Malvaceæ sp.-----	27
Nut rush (<i>Scleria</i> sp.)-----	3	Escoba (<i>Sida</i> sp.)-----	28
Sedge (<i>Carex</i> sp.)-----	12	Bretonica prieta (<i>Melochia nodiflora</i>)_	2
Sanguinaria (<i>Tradescantia</i> sp.)-----	3	Flacourtaceæ sp.-----	6
Star grass (<i>Hypoxis</i> sp.)-----	7	Nightshade (<i>Solanum</i> sp.)-----	1
Wild fig (<i>Ficus crassinervia</i>)-----	2	Nigua (<i>Tournefortia</i> sp.)-----	1
Wild fig (<i>Ficus</i> sp.)-----	1	Llanten (<i>Plantago</i> sp.)-----	1
Knotweed (<i>Polygonum</i> sp.)-----	3	Rubiaceæ sp.-----	6
Goosefoot (<i>Chenopodiaceæ</i> sp.)-----	19	Gherkin (<i>Cucumis</i> sp.)-----	3
Cenizo (<i>Chenopodium album</i>)-----	2	Concombre (<i>Cucumis anguria</i>)-----	1
Pigweed (<i>Amaranthus gracilis</i>)-----	1	Dog fennel (<i>Anthemis</i> sp.)-----	2
		Compositæ sp.-----	9

MONA GROUND DOVE. *Chamæpelia passerina exigua* Riley.

ROLITA, ROLA.

The subspecies of the ground dove found on the island of Mona (the type locality) is reported by Bowdish, the original collector, as abundant there from August 9 to 21, 1901. It has without doubt the same habits as the mainland subspecies, but differs from it in being smaller and paler. No ground dove was found on Desecheo Island.

PORTO RICAN DOVE. *Zenaida zenaida lucida* Noble.¹

TORTOLA, SANJUANERA.

The Porto Rican dove is common all through the region covered by this report. On Porto Rico it is largely a bird of the cultivated valleys and lowlands, roosting in clumps of trees, coffee plantations, or small areas of second growth and flying down to feed morning and evening in the fields and citrus groves. Its flight is strong and direct, and it flushes with a loud clapping of wings. On the ground it resembles the mourning dove, as it walks quickly about with nodding head, and has a cooing note almost indistinguishable from that of the latter bird.

During the breeding season the males frequently sail out in circles, with wings held stiffly, and their cooing notes come from the hillsides all day long. Several times, while mating, males were seen walking rapidly about on the ground near the females, striking at each other with their wings. Breeding birds were taken in February and a young bird, not quite adult but able to fly, was collected near Manati July 8. Although in some localities the birds nest on the ground, here they must nest in the trees, or they would not be able to hold their own against the mongoose.

¹ Proc. New Engl. Zool. Club, V, Oct. 4, 1915, p. 101.

Between 9 and 10 in the morning the birds come to the streams and ponds for water, usually in pairs, flying swiftly, high in the air. On the gravel bars of the larger rivers they walk about quickly, quenching their thirst, and picking up bits of sand and gravel. Usually they are wary, but sometimes prefer to hide at the approach of an intruder rather than fly.

Food.—As in the case of the ground dove, this zenaida dove may be considered entirely vegetarian in its diet. In 22 stomachs examined, animal matter was found only four times. Two birds had eaten bits of the chrysalis of a lepidopteran, one had found fragments of a beetle, and another had taken a snail (*Truncatella* sp.), perhaps along with gravel. These combined amount to only 0.36 per cent, indicating that this dove practically confines itself to vegetarian fare. Seeds comprise its principal diet, only small quantities of other vegetable matter, perhaps leaves, being found. Grass and sedge seeds figure to a less extent than in the food of the ground dove, while there is a corresponding increase in wild legumes, larger euphorbias, mallows, and others. Seeds of knotweed, goosefoot, pigweed, and purslane were eaten, as well as large quantities of caltrop and mallows.

One bird had secured grains of hedionda (*Cassia occidentalis*), which is used as a substitute for coffee, and another had eaten seeds of a citrus fruit, perhaps of an orange. The latter, however, were almost certainly taken from the ground, not from the fruit itself, as this dove is incapable of tearing open undecayed fruit. Three birds taken near Comerio had eaten rice, of the inferior red variety, which may well have been picked up as waste. None of the others examined had eaten grain, a strange fact when the habits of the bird are considered. The birds were observed in the field eating fruit of the moral (*Cordia* sp.), and pits of this fruit were found in two stomachs. On Vieques Island they were said to eat other fruits, as do the larger pigeons, but no trace of such was found. The little damage that they do in eating grain is more than offset by the injurious seeds destroyed. Thus the bird may be considered of some value to the landholder, in addition to being a game bird of importance. As this species frequents the open country, it is well able to adjust itself to changing conditions and with proper regulations will remain a common game bird. The same restrictions should be placed on its pursuit as on that of the other large pigeons.

The following seeds and fruits were eaten by the zenaida dove:

Paspalum (<i>Paspalum</i> sp.)	1	Orange (?) (<i>Citrus</i> sp.)	1
Panic grass (<i>Panicum</i> sp.)	4	Espino (<i>Xanthoxylum</i> sp.)	1
Broad-leaved olyra (<i>Olyra latifolia</i>)	1	Euphorbiaceæ sp.	9
Arroz (<i>Oryza sativa</i>)	3	Jatropha (<i>Jatropha</i> sp.)	3
Nut rush (<i>Scleria</i> sp.)	9	Malvaceæ sp.	4
Knotweed (<i>Polygonum</i> sp.)	1	Escoba (<i>Sida</i> sp.)	1
Goosefoot (<i>Chenopodaceæ</i> sp.)	2	Cadillo (<i>Urena lobata</i>)	2
Pigweed (<i>Amaranthus</i> sp.)	1	Passifloraceæ sp.	1
Verdolaga (<i>Portulaca oleracea</i>)	1	Adelia (<i>Adelia</i> sp.)	1
Cardosanto (<i>Argemone</i> sp.)	3	Morning glory (<i>Convolvulaceæ</i> sp.)	1
Senna (<i>Cassia</i> sp.)	2	Nightshade (<i>Solanum</i> sp.)	1
Hedionda (<i>Cassia occidentalis</i>)	1	Yerba mora (<i>Solanum nigrum</i>)	1
Fabaceæ sp.	11	Moral (<i>Cordia</i> sp.)	2
Vetch (<i>Vicia</i> sp.)	1	Trumpet flower (<i>Tecoma</i> sp.)	1
Wild bean (<i>Phaseolus lathyroides</i>)	3	Llanten (<i>Plantago</i> sp.)	1
Yerba rosario (<i>Æschynomene</i> sp.)	2	Compositæ sp.	1
Caltrop (<i>Kallstromia mazima</i>)	2		

[**MOURNING DOVE.** *Zenaidura macroura macroura* (Linnaeus).
TORTOLA.

The mourning dove has been variously attributed to Porto Rico, but has not been unquestionably recorded. Ledru (1810, p. 208) has the earliest record and is followed by

Hartlaub (1847), who is quoted by Sundevall (1869, p. 601). Mr. Bowdish tells me that in some way he confused this bird with *Zenaida zenaida lucida*, as the notes and actions of the two are similar, so that his record (1902-3, p. 361) is not available. I watched carefully for this species on the island and made many inquiries concerning it without success.]

WHITE-CROWNED PIGEON. *Columba leucocephala* Linnæus.
PALOMA CABEZIBLANCA, VIEQUERA, TORCAZA.

The white-crowned pigeon was formerly one of the most abundant species in Porto Rico, but now is found only in a few localities. Gundlach (1878, p. 345) spoke of it as very common in the seventies, but its numbers have undoubtedly greatly decreased. The birds occur mainly near the coast, usually in dense swampy growths, though one was seen near Aibonito; and the few small areas of forest remaining in the lowlands may account for their diminution in numbers. Around Punta Picua, north of Mameyes, they were found preparing to breed in the swamps, where the growth was so dense that it was hard to get near them. They usually came out into the more open portions late in the evening, to feed on the fruit of the icaco (*Chrysobalanus* sp.), but even then kept well concealed in the thick leaves. The birds flushed with a loud clapping of wings, and flew strongly, making wide sweeping circles, or darting swiftly through the trees. In the heat of the day they perched in high trees over the swamps, resting quietly on dead limbs.

The first of July they were fairly common in the dense brush near the lagoons to the north of Manati. In May and June, when various fruits are ripe, they gather in considerable flocks and visit regions where they are unknown at other times.

Food.—Five stomachs examined contained vegetable matter only, composed of drupes and fruits of fair size. The icaco and berries of various palms (palmo real and lluma) are favorites with these birds, while a tree known as palo blanco (*Drypetes* sp.) is said to furnish them food in season. No cultivated crop is injured, the bird depending wholly upon wild fruits for its sustenance. With the clearing of the remaining forest areas in the lowlands this species will, without doubt, become practically extinct. At present, however, it has a certain importance as a game bird, and for its protection the same measures apply as for the scaled pigeon (p. 54).

The following were identified in the stomachs examined:

Palmo (<i>Coccothrinax</i> sp.)-----	1	Fabacæ sp.-----	1
Icaco (<i>Chrysobalanus</i> sp.)-----	2	Adelia (<i>Adelia</i> sp.)-----	1
Icaco (<i>Chrysobalanus pellocarpus</i>)----	1	Moral (<i>Cordia</i> sp.)-----	1

SCALED PIGEON. *Columba squamosa* Bonnatere.
PALOMA TURCA.

The large scaled pigeon is resident in Porto Rico in the mountain regions, and is common in the higher inaccessible portions where areas of forest still remain. A few were seen on Vieques and Culebra, where formerly they were said to be common. From all accounts they are abundant on Mona, and occur on Desecheo also, at times in considerable numbers. In the dense forests covering the slopes of El Yunque de Luquillo, in the northeastern part of Porto Rico, great numbers were noted. In the late afternoon and evening it was common to see them circling high in the air near the Hacienda Catalina, while in the forests they abounded up to 2,500 feet altitude. It was surprising how well 25 or 30 of these big pigeons roosting in the thin foliage of a cacao rosetta tree (*Sloanea berteriana*) managed to keep hidden. The ordinary call note was a loud, strongly accented *who hoo hoo*, while a burring guttural *hoo-o-o-o*, given with a throaty rattle, was almost startling when directly overhead. Many pigeons fed

in the tall trees fringing small streams at the foot of the mountain, while some were found in the dense swampy forests near Punta Picua, beyond Mameyes.

It is commonly believed in Porto Rico that the scaled pigeon is found there only as a migrant. This belief, fostered mainly by gunners who desire an open season covering the entire year, is erroneous, as was proven on March 8, when on El Yunque three nests were found without special search, while there was no doubt whatever that the dozens of birds flushing on every hand were breeding birds.¹ The three nests located were about 15 feet from the ground on horizontal limbs, or on refuse piled on large air plants, and were made of sticks loosely piled together. Two were empty, while one contained a single white egg of about five days' incubation. At Maricao on June 1 a native brought in a young bird about two-thirds grown, and said it was the only one in the nest. Gundlach (1878, p. 344) says that the birds lay two eggs, but from these instances it would seem that a single egg in a set is not unusual.

Scaled pigeons are said to occur in fall in large flocks and to gather in great numbers where certain fruits are ripening, and at that time many are killed. There is, however, apparently some migration between the various Antillean islands, as the number of birds on Desecheo Island, for example, is said to vary greatly from one season to another.

Food.—Wild berries and fruits with an occasional succulent leaf or other bit of herbage make up the entire fare of this pigeon. Ten stomachs reveal vegetable matter only. The berries of various palms are favorite foods and wild figs when in fruit draw large numbers of birds. The moral (*Cordia* sp.) and jagua (*Genipa americana*) are eaten extensively and one bird had taken quantities of a wild legume. All of the smaller wild fruits in season appear to furnish food, and these are so abundant that cultivated fields are not molested. The fruits eaten, though sometimes of comparatively large size and with hard stony pits, are swallowed entire. The strong muscular gizzard of the bird has a tremendous tritulating power, however, and the fruits are easily crushed and the meaty centers opened to the processes of digestion.

The paloma turca is the one game bird of importance in the inland region, because of its large size and universal distribution. Hunting it may be considered true sport, as the birds are wary, strong of wing, and can be pursued successfully only in the wildest, roughest country. It should be encouraged by every means possible, most of all by a close season extending from February 1 to October 15, to allow ample time for rearing the young. In addition there should be a bag limit of not more than 10 birds for one day.

The following were identified in the stomachs examined:

Palma de Sierra (<i>Acrista monticola</i>)-----	1	Lauraceæ sp.-----	1
Palmo (<i>Coccothrinax</i> sp.)-----	1	Storax (<i>Styrax portoricensis</i>)-----	1
Wild fig (<i>Ficus crassinervia</i>)-----	2	Nightshade (<i>Solanum</i> sp.)-----	1
Wild fig (<i>Ficus levigata</i>)-----	1	Moral (<i>Cordia</i> sp.)-----	1
Fabaceæ sp.-----	1	Jagua (<i>Genipa americana</i>)-----	1
Guaraguou (<i>Trichilia</i> sp.)-----	1		

[RING-TAIL PIGEON. *Chloranas caribæa* (Jacquin).

PALOMA.

Ledru (1810, p. 208) speaks of the ring-tail pigeon and Wagler¹ includes Porto Rico in its range. Gosse² says that Mauge, the zoologist who accompanied Ledru, found the species in flocks of many hundreds. It may have occurred formerly in Porto Rico, but no specimens are known at present, and as the old records are rather doubtful the species must be considered hypothetical.]

¹ Systema Avium 1827, p. 46.

² Birds of Jamaica, 1847, p. 296.

BLUE PIGEON. *Chlorænas inornata exsul* Ridgway.¹

PALOMA SABANERA.

The blue pigeon is now rare in Porto Rico. Gundlach (1878, p. 343) found a few near Lares in July and Stahl (1883, p. 148) had a female in his collection. They were reported to the writer several times and seemed to be found in the coastal region, though no definite localities were known. As the name was familiar to sportsmen, the birds doubtless have been shot in recent years. This species should be included with the paloma turca in any restrictions upon hunting (see p. 54).

SANTO DOMINGO PAROQUET. *Conurus chloropterus* (Souancé).

PERIQUITO.

Cory (1892a, p. 228) referred a paroquet taken on Mona Island by W. W. Brown, jr., to the species *Conurus chloropterus*, and permitted the writer to examine this bird and a small series from Santo Domingo. The specimen from Mona unquestionably belongs to this species, though with further study it may be differentiated as a subspecies from the Santo Domingan bird. Gundlach (1878, p. 229) received three wings from Mona Island taken by Block, and these were later described as *C. gundlachi* by Cabanis. Bowdish found no paroquets on Mona, and the writer made careful inquiries when on the west coast among the fishermen who visited Mona regularly, but could learn nothing regarding them. One man claimed to have lived there a year without seeing them, though he was able to describe the other birds of the island accurately.

There is reason to believe that at one time there existed a species of paroquet in Porto Rico, but it has long been exterminated. According to the British Museum Catalogue of Birds, it is represented by the type in the Paris Museum and by an additional specimen at Leyden. Gundlach was told of a paroquet formerly common in the eastern interior of Porto Rico and on Vieques Island, but long since extinct. Stahl (1887, p. 448) says that some of the oldest inhabitants had heard from their parents of this bird, but that it had disappeared long ago. Bowdish (1902-3, p. 20) heard of its occurrence near Lares, but I could find no one who knew anything about it. There were numerous paroquets in captivity in Porto Rico, but they were either *C. wagleri*, from Venezuela, or more rarely *C. chloropterus*, imported from Santo Domingo.

PORTO RICAN PARROT. *Amazona vittata* Boddaert.

COTORRA.

Fifteen years ago the parrot was a common species in Porto Rico and on Culebra,² but now has disappeared except in a few localities, mainly in the northeastern portion of the island, on El Yunque and immediately around its base. Twenty or more ranged through the dense, swampy forests north of Mameyes, perhaps 50 were seen around the west fork of the Rio Mameyes, a number were heard calling in the dense forests covering the summit of El Yunque itself, and they are said still to be fairly common around Preston's ranch above Naguabo. They have practically disappeared farther west, though reported from below San Sebastian, and Mr. Leopold B. Strube, of the Hacienda Jobo, between Arecibo and Utuado, said that during winter 50 or 60 were found on his plantation, though none nested there.

Near Mameyes parrots remained in the swamps during the day, coming out to the borders morning and evening to feed, but when alarmed flew back immediately. Sometimes a small flock fed in company with white-crowned pigeons

¹ Proc. Biol. Soc. Washington, XXVIII, May 27, 1915, pp. 106-107.

² Mr. Ridgway has separated the bird from Culebra as *Amazona v. gracilipes*. (Proc. Biol. Soc. Washington, XXVIII, May 27, 1915, p. 106.)

in the tops of the trees, but from their green coloration the parrots were the less conspicuous. Frequently they remained quiet in the trees for half an hour or more and then flew out in sudden alarm.

Around El Yunque the parrots were somewhat tamer, as they were not hunted so much, and a few were secured about a large clearing above the Rio Mameyes. The birds were in pairs or small bands during March and were then breeding. During early morning and evening they fed in the forest, but in passing back and forth stopped in the high dead trees of the clearing. They also came here to dry their feathers after the heavy rains that came at intervals during the day. When it rained heavily on the mountain many birds descended to the warmer valleys, returning when the weather cleared. The call note, given on the wing when alarmed, was a rapid, strident *kār, kār* that could easily be heard a mile away, and served to alarm the entire forest. When feeding, low chuckling notes were frequently heard. In the trees the birds watched intruders suspiciously or went through the characteristic posturings of *Amazona* in captivity, swinging head down and then climbing back by the aid of their bills.

These birds nest during March and April, and are said to lay two eggs, depositing them in a hollow tree. They are greatly sought after by the natives, who keep the young as pets and teach them to speak a few words of Spanish. Most of the captive birds on the island, however, are brought from Santo Domingo. The adults also are hunted as game birds, and prized for their flesh. Formerly when there were large forest areas on the island the birds were very common and, traveling in large bands, damaged cornfields, gonduros, etc. Men engaged in school work said that, as late as 1903, children were frequently kept at home to drive the parrots out of the fields. The handful remaining is now too small to do any great damage, and the birds should be protected, or one of the most interesting forms will soon be lost from the avifauna of the island.

Food.—The parrot seems to be almost entirely frugivorous, all of the wild fruits being eaten in season. It is very fond of the wild fig (*Ficus* sp.) and the jagua (*Genipa americana*), while in the swamps near Mameyes the ground beneath icaco trees (*Chrysobalanus* sp.) was strewn with husks which the birds had dropped. In eight stomachs examined, vegetable matter only was found, seeds of tabonuco (*Dacryodes excelsa*) and allied species in the same family (Burseraceae) greatly predominating. A bird taken near Mameyes had eaten icacos (*Chrysobalanus* sp.) and its stomach contained also a few bits of wood. In the birds secured on El Yunque the stomachs were usually filled with small seeds while the crops were distended with larger fruits and drupes. The hard seeds in the gizzard seem to take the place of gravel used by many birds as a triturating element, and while they serve to grind up larger fragments are in their turn pulverized and utilized as food. Wherever parrots were common the ground was always littered with seeds, bits of pericarp, and other waste matter which they had discarded.

[BLACK-BILLED CUCKOO. *Coccyzus erythrophthalmus* (Wilson).
PAJARO BOBO.

The black-billed cuckoo is of doubtful occurrence in Porto Rico. Gundlach included it on the strength of a drawing in the album of Bello, who received the bird from the interior of the island.]

YELLOW-BILLED CUCKOO. *Coccyzus americanus* (Linnæus).
PAJARO BOBO, PAJARO BOBO DE COSTA.

On August 27 a cuckoo heard calling in an almendra grove at Joyuda near Cabo Rojo was secured as it sat in the sun on a low limb; it proved to be

the yellow-billed species. It was immature, and if not native must have been on the island for several days, as it was molting badly, having but two tail feathers. Another, thought to be this species, was heard August 31 near the same locality, but could not be found. Gundlach (1878, p. 232) records the species near Mayagüez, Aguadilla, and Arecibo. Bowdish (1902-3, p. 364) secured two near Aguadilla, May 18 and 20, 1900, and one on Mona, August 17, 1901. Thus the birds seem to be possible residents or regular migrants here in small numbers. They have the habits of the mangrove cuckoo, and thus far have been recorded only from the western end of the island, with the single exception of Gundlach's Arecibo record.

Food.—The only bird examined had eaten 15 caterpillars of two species and 3 sugar-cane root-boring weevils (*Diaprepes spengleri*). It is to be hoped that a bird capable of doing so much good may become more common over the entire island.

MANGROVE CUCKOO. *Coccyzus minor nesiotes* Cabanis.
PAJARO BOBO, PAJARO BOBO MENOR.

The mangrove cuckoo is a tolerably common resident species in this region. Many were found in mangrove swamps, coffee plantations, and in dense thickets overgrown with vines along small streams; but being of retiring habits, they were easily overlooked. In dry brush-covered areas, as on the smaller islands, they were especially common. The call notes are loud and sonorous and closely resemble those of the yellow-billed species. In the morning the birds frequently were seen sitting quietly in the sun on dead limbs, sometimes calling from these perches. Slow and methodical in their movements, they frequently remain motionless for several minutes and seldom fly far. On March 25, birds on Vieques Island were about to breed. The breeding season is of irregular extent, but appears to continue until October.

Food.—Fifteen stomachs were available for laboratory examination, and in these animal matter amounted to 99 per cent, Orthoptera and Lepidoptera (nearly all caterpillars) forming the main bulk of it. The vegetable matter (1 per cent) consist of a small quantity of rubbish found in one stomach secured in February. The true grasshoppers (Locustidæ) form 50.31 per cent of the food and occurred in 13 of the 15 stomachs examined. The eggs as well as the insect itself are eaten, one stomach containing 32 of them. A cuckoo taken on Culebra Island in April had eaten a single mole cricket, but this forms only 0.21 per cent of the total food. Walking sticks in four stomachs and a small cricket (*Ellipes minuta*) in one make 3.1 per cent, and one bird had eaten a praying mantis. Earwigs were taken by three birds. Cicadas (*Proarno hilaris*) in two stomachs and stink bugs in another form 6.09 per cent. Caterpillars occurred in nine stomachs and a moth in one, and together they amount to 29.52 per cent. Not much can be said regarding these, as the island species are not sufficiently well known, but undoubtedly they are all injurious. It is gratifying to learn that this cuckoo is as active in their destruction as are its better-known northern congeners, the yellow- and black-billed cuckoos of the United States. As is frequently the case with the northern species, several stomachs were lined with caterpillars' spines stuck in the walls of the stomach. Various beetles, almost all destructive weevils, form 3.59 per cent of the food. Scarred-snout beetles and a small curculionid (*Rhyssomatus* sp.) were among the most important beetles taken. Spiders form 4.06 per cent of the total, and miscellaneous matter, fragments of a hymenopteran, a snail, and remains of earwigs figure as 1.83 per cent.

The mangrove cuckoo, with its appetite for Orthoptera and injurious caterpillars, is one of the most beneficial birds of the island. It has been accused

without corroboration of eating other bird's eggs, but at present no evil is known of it. It will be noted that this is one of the few insectivorous birds of any size on the island that do not prey more or less upon the abundant lizards.

The following were identified in the stomachs of the mangrove cuckoo:

ORTHOPTERA.		COLEOPTERA.	
<i>Ellipes minuta</i> -----	1	<i>Pyrophorus luminosus</i> -----	1
<i>Orocharis terebrans</i> -----	2	<i>Lachnosterna</i> sp-----	1
<i>Scapteriscus didactylus</i> -----	1	<i>Eburia</i> sp-----	1
<i>Microcentrum triangulatum</i> -----	2	<i>Lachnopus</i> sp-----	2
<i>Neoconocephalus</i> sp-----	2	<i>Diaprepes spengleri</i> -----	1
<i>Aploplus achalus</i> -----	1	<i>Rhyssematus</i> sp-----	1
<i>Callimantis antillarum</i> -----	1		
HEMIPTERA.		ARACHNIDA.	
		<i>Avicularia</i> sp-----	1
		MOLLUSCA	
<i>Thyanta perditor</i> -----	1		
<i>Proarno hilaris</i> -----	2	<i>Subulina</i> sp-----	1

VIEILLOT'S GROUND CUCKOO. *Saurothera vieilloti* Bonaparte.

PAJARO BOBO, PAJARO DE AGUA, PAJARO BOBO MAJOR.

The ground cuckoo is a fairly common resident species in Porto Rico. In spite of its large size it is very inconspicuous, and its long tail, instead of making it prominent, aids its protective coloration by giving it rather an unbirdlike contour. In passing through the trees, the birds usually keep to the densest foliage and make long pauses, during which they sit motionless or merely turn the head slightly. In early morning they may be found in dead trees or on exposed limbs, where they sit in the sun with drooping wings and ruffled feathers. They are very tame and show no fear of man. Though seen occasionally on the ground, they seem to spend most of their time in bushes and trees. The ordinary call notes, heard frequently, are cuckoolike and resemble the syllables *cow cow*, *kuk krrk* given disconnectedly. Sometimes a cuckoo would perch in the top of a tree, giving a sonorous almost ravenlike note, and on one occasion one was seen standing on a limb with trembling wings, giving utterance to a low cooing note. In some localities the name "pajaro de agua" was given them because of the belief that they called only before an approaching rain—a prophecy that usually came true. They were more common inland in the coffee plantations, but were encountered in the swampy forest near Mameyes and elsewhere near the coast.

A. and E. Newton¹ record one taken on Bieque (Vieques Island) by a collector for Apotheker Riise, of St. Thomas, the only known record of the bird outside the island of Porto Rico.

Food.—Tabulated results of examinations of 11 stomachs show 99.89 per cent animal matter. A small percentage of vegetable rubbish was found in two stomachs, but nothing that can be called true vegetable food was taken. Small lizards make up more than three-fourths of the bulk, and a few spiders, Lepidoptera, and cicadas form most of the remainder.

Lizard remains occurred in 10 stomachs, and in many cases small ones were found entire. Frequently, however, when torn in two, the contents of their stomachs (ants and small beetles) usually mingled with the food of the bird itself, so that care was necessary in separating this material. Four species of lizards were identified, but all the small ones found in the forests and coffee plantations are eaten. They make 78.56 per cent of the food. Spiders, fre-

¹ Ibis, 1859, p. 378.

quently of large size, form 6.85 per cent, and cicadas (*Proarno hiliaris*) 4.16 per cent. Caterpillars in six stomachs and moths in two together comprised 7.92 per cent. Coleoptera amount to only 0.92 per cent, and about half of this food consisted of weevil remains, the rest of fragments of longicorns (*Leptostylus* sp.) and a leaf beetle (*Mesomphalia* sp.). Earwigs were eaten three times and orthopteran remains occurred twice.

In consuming such quantities of lizards this bird must be considered injurious, though to some extent it makes up for this by a diet of pernicious caterpillars, and in case of serious outbreaks of these pests this cuckoo could do good work in suppressing them. The bird is not common enough to make a reduction of its numbers necessary, nor under present conditions will it become so. Though many lizards are destroyed, they still hold their own. The ground cuckoo has from all accounts diminished greatly in numbers in the last 40 years and is no longer present in sufficient numbers to be of economic importance.

The following were identified in the stomachs examined:

HEMIPTERA.		REPTILIA.	
<i>Proarno hiliaris</i> -----	4	<i>Anolis</i> sp.-----	7
COLEOPTERA.		<i>Anolis cristatellus</i> -----	1
<i>Leptostylus</i> sp.-----	1	<i>Anolis krugi</i> -----	2
<i>Mesomphalia</i> sp.-----	1	<i>Anolis gundlachi</i> -----	1
<i>Rhyssomatus</i> sp.-----	1	<i>Anolis stratulus</i> -----	1
ARACHNIDA.			
<i>Theraphosidae</i> -----	1		

ANI. *Crotophaga ani* Linnaeus.

JUDIO.

The ani is a common resident species in Porto Rico. These strange birds are found in flocks of from half a dozen to 20 or more, principally in pastures, but also in cane fields and orange groves, where they sometimes feed. In the pastures they remain near the cattle, keeping ahead of them with long hops, presumably to get the insects scared up. An intruder is greeted with a querulous call, and the whole flock goes stringing off across the fields to perch in a bush or low tree, where they crowd together and peer out curiously, their long tails and arched beaks producing an odd appearance. In early morning, when the grass is wet, they frequently sit with wings extended, drying them in the sun. The wings are small for the size of the bird, and the flight, a series of steady wing beats alternating with short sails, is not strong. In a heavy wind the birds are almost helpless and seldom rise very high at any time. When on the wing the back appears concave, as the head and tail are held higher.

On Culebra Island these birds fairly swarmed in the pastures. They are said formerly to have been as common on Porto Rico, but to have lessened in numbers greatly since the introduction of the mongoose. As they are much on the ground the mongoose could surprise them often. In the heat of the day they usually take refuge in the shade of dense clumps of bamboo along streams. They also roost in these at night, as well as in the mangroves around the lagoons. The ordinary call notes are a low *kur-r-rk*, and a querulous *quee ick quee ick* varied by low chuckling notes. When the birds are at all wild they serve to alarm the entire country, as they begin to call immediately upon perceiving a strange object. Although they occur in the pastures in the higher altitudes, they are not at all common except lower down.

The breeding season varies greatly. A female containing a fully formed egg was taken near Rio Piedras December 20, and breeding birds or young in first

plumage were noted until field work was completed in September, so that apparently they nest the year round. Although these birds often build communal nests, this is not always the case. Near Cayey, January 22, a pair were seen constructing a nest in a tree about 30 feet above a small stream, the male sitting on a limb above while the female was in the nest, as yet only a loose mass of sticks and weeds, moving and turning to shape it to her body, her long tail sticking nearly straight up in the air. July 25, near Bayamon, a single bird slipped quietly from a bulky nest in a clump of bamboos and only its mate appeared to join it. The nests seen ranged from 6 (Vieques Island) to 30 feet above the ground and were all large and bulky.

On May 20, near Yauco, three anis were seen in a tree in which several mozambiques had nests. The anis were right at the nests, and the blackbirds, together with a pair of gray kingbirds, were much excited, but appeared to be unable to drive away the intruders. The anis were evidently bent on robbing the nests, and one was shot in the act of gulping down something, which was found to be an egg. No other instances of this egg-eating habit were observed.

Food.—In 41 stomachs of the ani animal matter forms 91.3 per cent and vegetable 8.7 per cent. Orthoptera make up the largest item of animal food, with Coleoptera next, while large quantities of true bugs and caterpillars were taken. Vegetable matter was made up almost entirely of seeds and wild fruits, with a little rubbish secured with other food.

Animal food.—Orthoptera, the largest part of the food of this bird, form 41.58 per cent. Mole crickets (*Scapteriscus didactylus*) occur in five stomachs and make 5.69 per cent, forming an important element of the food. Locusts (Acrididae) were eaten 21, and katydids (Locustidae) 24 times, and these, with cricket remains in 6 instances, amount to 35.8 per cent. These are picked up on the ground and are all injurious insects. Predacious mantids were found in three stomachs, but compared with other Orthoptera form a very small bulk. The largest quantities of Orthoptera are found from December to May and the smallest in July and August.

Of Coleoptera, weevils (14.81 per cent) are the best represented, and are injurious almost without exception. The one occurring most is the destructive cane root-borer (*Diaprepes spengleri*), which was found in 14 stomachs and amounts to 7.09 per cent. The adult weevil is common in pastures and fields frequented by the ani and offers them an easily secured means of subsistence. It is known to feed not only upon the sugar cane but also upon the roots of orange trees. The larval form of this weevil, known as *el gorgojo-barreno de las raices*, is safe from bird enemies except at plowing time, but the adult is open to attack at all seasons. The weevil stalk-borer, *el gorgojo-barreno in los tallos*, was eaten once. A single predacious ground beetle (*Calosoma alternans*) was eaten, as well as two others (*Selenophorus* sp.), of doubtful character. Leaf beetles amount to 3.61 per cent; among them a green diabrotica (*Diabrotica graminea*), known to injure cane and various vegetables by eating the leaves, was taken eight times. Miscellaneous beetles amount to 4.72 per cent and Scarabæidae to 0.21 per cent, consisting entirely of small species (*Aphodius* and *Atenius*). In this great mass of beetles only one ladybird (*Cycloneda limbifer*) was found.

Squash bugs (Pentatomidae) form 9.24 per cent and were present in 22 instances. They are known to be more or less injurious and, unsavory and ill smelling as they are, appear to be freely eaten by the ani. Miscellaneous Hemiptera form 1.22 per cent and are composed of stray water boatmen and back swimmers with a few predacious ambush and assassin bugs and others.

Caterpillars were found in 17 stomachs and moths in 7, and form 9.71 per cent. In some cases almost an entire meal was made from caterpillars, one

bird alone having eaten 38. Spiders were taken freely, but amount to only 4.08 per cent. Strangely enough, no cattle ticks were found, though it is the universal belief that the ani consumes many, and from that fact indeed is derived its generic name.

Miscellaneous animal matter amounting to 1.45 per cent is composed of a wide range of material. Fragments of a dragon fly, a dipteran, and crustacean remains each occur once. One stomach contained a peculiar flat platelike tooth from some fish, and only two contained lizard remains. The bird, shot in the act of robbing a blackbird's nest, contained large fragments of eggshell.

The following were identified in the stomachs of the ani:

ORTHOPTERA.		COLEOPTERA—continued.	
<i>Schistocerca</i> sp.....	5	<i>Cycloneda limbifer</i>	1
<i>Schistocerca columbiana</i>	1	<i>Monocrepidius bifoveatus</i>	1
<i>Plectrotettix</i> sp.....	6	<i>Aphodius lividus</i>	1
<i>Plectrotettix gregarius</i>	2	<i>Atenius stercorator</i>	2
<i>Homorocoryphus</i> sp.....	1	<i>Chlorida festiva</i>	1
<i>Conocephalus</i> sp.....	1	<i>Diabrotica graminea</i>	8
<i>Neoconocephalus</i> sp.....	1	<i>Ceratoma denticornis</i>	2
<i>Neoconocephalus macropterus</i>	1	<i>Lema</i> sp.....	2
<i>Callimantis antillarum</i>	1	<i>Coptocycla signifera</i>	3
<i>Anurogryllus</i> sp.....	1	<i>Chaetocnema</i> sp.....	1
<i>Anurogryllus muticus</i>	1	<i>Myochrous</i> sp.....	1
<i>Gryllus assimilis</i>	1	<i>Rhyssematus</i> sp.....	8
<i>Scapteriscus didactylus</i>	5	<i>Metamasius hemipterus</i>	1
HEMIPTERA.		<i>Lachnopus</i> sp.....	4
<i>Corixa</i> sp.....	1	<i>Diaprepes spengleri</i>	14
<i>Notonecta</i> sp.....	2	HYMENOPTERA.	
<i>Zelus</i> sp.....	2	<i>Spilochalcis</i> sp.....	1
<i>Phymata angulata</i>	1	<i>Megachile</i> sp.....	1
<i>Corizus</i> sp.....	1	<i>Solenopsis geminata</i>	1
<i>Catorhintha</i> sp.....	1	<i>Vespa</i> sp.....	1
<i>Spartocera fusca</i>	1	ARACHNIDA.	
<i>Edessa</i> sp.....	1	<i>Lycosa</i> sp.....	3
<i>Nezara</i> sp.....	3	<i>Oxyopes salticus</i>	7
<i>Proxys</i> sp.....	2	<i>Epeira</i> sp.....	1
<i>Thyanta</i> sp.....	4	<i>Argiope argentata</i>	1
<i>Thyanta perditor</i>	3	<i>Attidæ</i>	1
<i>Margarodes formicarum</i>	1	COLEOPTERA.	
<i>Calosoma alternans</i>	1	<i>Selenophorus</i> sp.....	2
<i>Selenophorus</i> sp.....	2		

Vegetable food.—The vegetable matter (8.7 per cent) was made up largely of the seeds of the cherrylike moral (*Cordia* sp.), which occurred in 15 of the 41 stomachs. It is doubtful whether seeds themselves appeal to this bird, as there were few in the stomachs which did not have a more or less pulpy exterior. The gizzard is hardly fitted for grinding up flinty seeds and in only one stomach was a trace of gravel found. In the field the birds were seen eating the icaco (*Chrysobalanus* sp.). None of the fruits taken are in any way the product of man's labor. The following seeds were identified in the stomachs:

<i>Whitetop</i> (<i>Dichromena</i> sp.).....	1	<i>Moral</i> (<i>Cordia</i> sp.).....	15
<i>Palm</i> (<i>Coccothrinax</i> sp.).....	1	<i>Concombre</i> (<i>Cucumis</i> sp.).....	1
<i>Espino</i> (<i>Xanthoxylum</i> sp.).....	4	<i>Compositæ</i> sp.....	1
<i>Euphorbiaceæ</i> sp.....	1		

Summary.—The judio or ani may be considered entirely beneficial, as it destroys large numbers of highly injurious orthoptera, beetles, and caterpillars.

The only evil that can be attributed to it is not appreciable when compared with the services rendered: a few beneficial insects are destroyed and one bird had robbed a blackbird's nest, an occurrence believed to be exceptional. As a whole, the bird is a valuable aid to the landowner and should be carefully protected.

PORTO RICAN WOODPECKER. *Melanerpes portoricensis* (Daudin).
CARPINTERO.

The woodpecker is common in Porto Rico and on Vieques Island wherever there are trees large enough to afford it shelter. At present it is rather rare in the coastal region, as the forests have been cleared for many years. In habits and notes it strongly resembles the red-headed woodpecker of the United States, and has many of the habits of that bird. The flight is strong and undulating, as with other woodpeckers, and, while the birds are not wild, they are not easy to approach if they suspect they are being followed. This is one of the few species common in coffee plantations. The woodpecker finds a congenial home in the trees shading the coffee, and searches their trunks constantly for insects. Occasionally in the early morning, from January until May, they were heard drumming a rapid tattoo on a dead limb.

The birds were seen excavating nesting holes in February, and apparently deposited eggs from April 20 to May 1. At Yauco one nest was still empty May 17. By May 29 a few young were seen on the wing near Maricao, and from then on they were common. Adults were very vociferous and anxious about the young and fed them for about two weeks after leaving the nests. These birds apparently remain mated throughout the year. Woodpeckers were often seen in early morning sunning themselves on dead stubs, as the red-heads do, but, seemingly indifferent to the passing insects, they made no attempt to catch them.

Food.—In 59 stomachs of this woodpecker animal matter amounts to 65.83 per cent and vegetable to 34.17 per cent. Wood-boring larvæ, ants, and earwigs form a large share of the animal matter eaten, and small wild fruits, with a certain proportion of rubbish, make up the vegetable food. The material examined represented the food of all the months from January to August.

Animal food.—Earwigs (Forficulidæ) (8.55 per cent) were found in 40 stomachs, usually only the oddly formed tail forceps surviving the process of digestion. Only one species (*Phaulex albipes*) was identified and it is apparently common on the island. Not much is at present known regarding the status of these insects, but it is possible that some of the larger tropical forms may be of economic importance. Orthopteran remains (1.03 per cent) were found in three stomachs only. One cricket was eaten. Larvæ of wood borers mainly of longicorn beetles were found in 32 stomachs and, with adult longicorns in 3 others, form 24.68 per cent. This woodpecker, frequenting the coffee plantations, thus aids in ridding the shade trees, so essential to good crops of coffee, of their pests. By means of its strong bill and long tongue it can uncover and drag out these destructive larvæ, protected from other birds beneath the bark. Weevil remains in 13 stomachs amount to 1.47 per cent and other Coleoptera figure as 3.99 per cent. Darkling beetles were found commonly, as many of them live underneath bark. All were difficult of identification, as hard insects are thoroughly broken up before being swallowed. Among the Hemiptera, eaten by seven birds (4.16 per cent), were two stinkbugs (Pentatomidæ) and two cicadas (*Proarno hilaris*).

Next to the wood-boring larvæ, ants (10.37 per cent) form the largest single item, being found in 42 stomachs, in several forming a large part of the contents. One species (*Myrmelachista ambigua ramulorum*) found in 14 stomachs

is very destructive in coffee plantations, where it makes canals in the pith of the new shoots of the coffee trees. When mature the shoots are frequently weakened so that they break when bent down by the pickers, injuring the trees and damaging the crop in many cases. One bird had eaten 81 of these ants, another 100, and others contained smaller numbers. A few caterpillars amount to 2.49 per cent and spiders to 1.37 per cent. The little arboreal tree toad or coqui (*Eleutherodactylus* sp.) was eaten by seven birds, and small lizard remains occurred in five stomachs, together forming 6.17 per cent. Miscellaneous animal matter (1.55 per cent) was made up of a single scorpion, whose sting was found in the stomach, a centipede, a wood louse, and two snails. Thus the animal food seems to consist almost entirely of material taken from the trunks of trees.

The following were identified in the stomachs examined:

CRUSTACEA.		COLEOPTERA—continued.	
<i>Cubaris</i> sp.-----	1	<i>Platydemia</i> sp.-----	2
EUPLEXOPTERA.		<i>Helops</i> sp.-----	3
<i>Phaulx albipes</i> -----	2	<i>Platypus</i> sp.-----	1
ORTHOPTERA.		HYMENOPTERA.	
<i>Leucophæa surinamensis</i> -----	1	<i>Solenopsis</i> sp.-----	1
HEMIPTERA.		<i>Myrmelachista</i> sp.-----	3
<i>Proarno hilaris</i> -----	2	<i>Myrmelachista ambigua ramulorum</i> -----	14
<i>Corixa</i> sp.-----	1	<i>Cardiocondyla emeryi</i> -----	1
COLEOPTERA.		<i>Monomorium floricola</i> -----	1
<i>Tropisternus</i> sp.-----	1	<i>Camponotus ustus</i> -----	2
<i>Atenius</i> sp.-----	1	ARACHNIDA.	
<i>Leptostylus</i> sp.-----	1	<i>Oxyopes salticus</i> -----	1
<i>Myochrous</i> sp.-----	1	VERTEBRATA.	
<i>Temnochila</i> sp.-----	1	<i>Eleutherodactylus</i> sp.-----	7
<i>Tenebrioides</i> sp.-----	1	<i>Anolis</i> sp.-----	3
		<i>Anolis krugi</i> -----	1

Vegetable food.—Seeds and small fruits form 24.93 per cent of the food and vegetable rubbish, composed almost entirely of bits of wood, 9.24 per cent. The berries of various palms and small fruits borne by rubiaceous shrubs, many of which could not be identified, seem to be most relished. Fruits of the camacey (*Miconia* sp.) and palo moro (*Psychotria* sp.) were discovered by field observations to be favorites, and below El Yunque one bird was seen picking at the scales at the base of the fronds of a tree fern or jelecho (*Cyathea arborea*). None of the fruits or seeds eaten are of commercial value.

The following seeds were identified:

Arecacæ-----	3	Espino (<i>Xanthoxylum</i> sp.)-----	1
Palm (<i>Coccothrinæ</i> sp.)-----	1	Euphorbiacæ sp.-----	5
Palma de Sierra (<i>Acrista</i> sp.)-----	2	Moral (<i>Cordia</i> sp.)-----	1
Wild fig (<i>Ficus</i> sp.)-----	5	Compositæ sp.-----	5
Fresa (<i>Rubus</i> sp.)-----	2		

Summary.—In some localities the woodpecker damages coconut palms by digging nesting holes in them. Water gathers in these holes and the trunk decays until finally the tree is broken by the wind. As it takes these palms five to seven years to mature, this means considerable loss. However, it was found that woodpeckers occurred in the palm groves only where areas of lowland

forest had been recently cleared, as at Punta Picua north of Mameyes, and that in the older groves they had not been seen for many years. It appears, then, that this is not a common habit with them, and that when discouraged the birds do not return. So that on the whole the woodpecker is to be considered beneficial. The only representative of its family in the region, it occupies a peculiar place in regard to insect pests, being able to combat those safe from the attacks of other birds and to aid in reducing the numbers of others less favored but none the less noxious. Where it does damage to the coconut groves a reduction of its numbers may be countenanced, but elsewhere it should be protected.

PORTO RICAN TODY. *Todus mexicanus* Lesson.

(PLATE I. Frontispiece.)

SAN PEDRITO, MEDIO PESO, PAPAGAYO, BARRANCOLINO, VERDADON.

The tody was common over the entire island of Porto Rico, usually being absent, however, from the lowlands and never reaching clear to the coast. It frequents dense forests, coffee plantations, or the brush-covered banks of streams in damp localities, but is also common in the dry hills of the south coast where there is no water. Though brilliantly colored, this little bird is very inconspicuous, the green of the back resembling the vegetation, while in the coffee plantations even the bright red of the throat may be mistaken for a ripe coffee berry. Todies are tame little fellows, keeping usually in the low growth and coming up almost within arm's reach. On warm mornings, after a day and a night of fog and rain, they are found in the trees above the brush, and then their true numbers may be appreciated. When perching they sit nearly upright, the large bill at an angle of 45°. The ordinary note is a loud, harsh *pree* or *pree-ah*, entirely disproportionate to the size of the bird. In calling it rises to the full length of the legs and points the bill up. Another habit is to fly out with a loud whirring rattle of the wings, apparently made by the attenuate outer primary. This is under the control of the bird, as sometimes the flight is noiseless. The sound is made by both sexes, mainly from January to June, but is seldom heard after the breeding season.

This little bird is one of the few species common in the dense forests on El Yunque, though here the fogs and heavy rains seem to subdue them somewhat, and only occasionally do they break out into their loud notes. They are said to begin nesting the first week in March, and birds taken then showed earth stains on the plumage. Apparently the eggs are not deposited until May or June, the young birds being common in July. The first nest seen was near Yauco on May 24. A bird flew up from the face of a cut bank in a dry pasture, and on examination the entrance to the nest was found, a hole about 1½ inches in diameter, showing the double path of an occupied nest. The tunnel went straight in through the hard earth for 10 inches, and then turned at a right angle, going 8 inches farther to the terminal chamber, a cavity 3 inches high, the same in width, and 5 inches deep. This nest contained three eggs, laid on the bare earth, of a size that was astonishing, considering the smallness of the bird. Each one was worked into a little hollow in the loose earth so that it was partly embedded, but even then it must have been a task for the female to cover them. They were a beautiful transparent white, showing a rosy reflection before blowing, and dull white afterwards. Another nest found in a claybank near Maricao June 3 consisted of a hole 1½ inches in diameter and 8 inches deep leading into a circular chamber 3 inches across. The nest contained two eggs, so stained by the red clay that they appeared to be densely spotted. Young were first seen near Quebradillas July 5, and after that were common. At first their throats are plain, but red feathers soon appear, and then they resemble

adults except for the shorter bill. The usual color of the iris in this species is grayish white, but in many it was plain slate.

These little birds are very active flycatchers, always watching overhead for insects, and capturing them on the wing with a loud snap of the bill, or picking them from the underside of leaves. In dry areas they frequently feed actively about the tips of twigs, and work through more open localities than is their usual habit.

Food.—In 89 stomachs of the tody, animal matter forms 97.62 per cent and vegetable 2.38 per cent. Flies, beetles, and small lantern flies form the most important elements of the animal food, and a few seeds compose the vegetable matter. In so small a bird the insects taken are of necessity of minute proportions, and from field observations little could be learned save that they seemed to feed to a considerable extent upon ants and small Homoptera.

Animal food.—Forty-nine of the birds taken had eaten odd, forcep-tailed earwigs, creatures of uncertain habit, and these form 9.4 per cent of the total. Orthoptera were seldom taken and amount to 2.28 per cent. The larger part of this is made up of grasshoppers, in six stomachs, while single birds had eaten a roach, a locust, and a mantis, all of small size. Small Homoptera, all of great economic importance, form 9.28 per cent. Small lantern flies (*Ormenis* sp.) are known to attack the young shoots of coffee, while leaf hoppers (*Tettigonia* sp.) are injurious to small crops and undoubtedly to larger trees. Other Hemiptera (1.11 per cent) comprise a miscellaneous assortment of ambush bugs, stinkbugs, and scale insects, the last two each found five times. The red scale (*Lecanium* sp.) was among those taken. Caterpillars in 9 stomachs and moth remains in 18 form 5.21 per cent. Though remains of Diptera figure as 30.88 per cent and were eaten by 65 birds, they were so broken and ground up that further identification was usually impracticable. Mosquitoes were identified certainly in one case and doubtfully in several others. They are, however, so easily broken up that they readily escape notice.

Beetles combined amount to 23.44 per cent, but the only useful ones found are ladybirds (Coccinellidæ). Though these occur in 21 stomachs, they amount to only 1.59 per cent of the total food. Snout beetles (6.47 per cent) were present in 46 stomachs. These can without doubt all be classed as injurious and alone more than outweigh the useful beetles eaten. Leaf beetles—Chrysomelidæ—(8.55 per cent) were present in 42 of the stomachs examined. Diabroticas and flea beetles of several species were the most common, and with them were others of uncertain economic position. As a whole, however, this family and the longicorn beetles (4.87 per cent) are to be considered injurious. The Hymenoptera eaten (4.33 per cent) weigh in the balance against the bird, as they are composed largely of parasitic chalcids and ichneumon flies. One peculiar sawfly, a plant-feeding species, with curiously forked antennæ, was found. Though many ants are consumed, one of their principal parasites (*Kapala* sp.) is eaten freely, being found in nine stomachs. Spiders in 38 stomachs amount to 8.17 per cent. Among the most unexpected discoveries were the remains of tiny lizards in five stomachs, and one can well imagine a vigorous struggle between this diminutive bird and some active anolis which objected to being swallowed. These with a few insect eggs amount to 3.52 per cent.

The following were identified in the tody stomachs examined:

ORTHOPTERA.		COLEOPTERA—continued.	
<i>Plectoptera poeyi</i> -----	1	<i>Diabrotica graminea</i> -----	3
HEMIPTERA.		<i>Haltica</i> sp-----	1
<i>Tettigonia</i> sp-----	14	<i>Glyptina</i> sp-----	1
<i>Tettigonia occatoria</i> -----	1	<i>Cerotoma</i> sp-----	6
<i>Ormenis</i> sp-----	6	<i>Lema</i> sp-----	2
<i>Oliarus</i> sp-----	1	<i>Physimerus</i> sp-----	2
<i>Macrocephalus</i> sp-----	1	<i>Calandra</i> sp-----	2
<i>Phymata</i> sp-----	1	<i>Platypus</i> sp-----	9
<i>Geocoris</i> sp-----	1	DIPTERA.	
<i>Lecanium</i> sp-----	1	<i>Psilopus</i> sp-----	7
COLEOPTERA.		<i>Eristalis</i> sp-----	1
<i>Hydrochus</i> sp-----	2	<i>Tetanops</i> sp-----	1
<i>Berosus</i> sp-----	2	<i>Euxesta</i> sp-----	8
<i>Cycloneda limbifer</i> -----	1	<i>Simulium quadrivittatum</i> -----	1
<i>Scymnus roseicollis</i> -----	1	HYMENOPTERA.	
<i>Scymnillus</i> sp-----	19	<i>Kapala</i> sp-----	9
<i>Loberus</i> sp-----	1	<i>Hyptia</i> sp-----	1
<i>Tenebrioides</i> sp-----	1	<i>Solenopsis</i> sp-----	1
<i>Microrhagus</i> sp-----	1	<i>Solenopsis geminata</i> -----	1
<i>Tylocerus</i> sp-----	1	<i>Macromischa</i> sp-----	1
<i>Catorama</i> sp-----	1	ARACHNIDA.	
<i>Atenius</i> sp-----	1	<i>Mogrus</i> sp-----	1
<i>Atenius gracilis</i> -----	1	<i>Epeira</i> sp-----	1
<i>Eburia</i> sp-----	3	VERTEBRATA.	
<i>Leptostylus</i> sp-----	3	<i>Anolis</i> sp-----	4
<i>Lepturges</i> sp-----	1		
<i>Cryptocephalus</i> sp-----	14		
<i>Cryptocephalus pusio</i> -----	1		
<i>Diabrotica</i> sp-----	1		

Vegetable food.—Little can be said regarding the vegetable food of the tody, as it is insignificant in volume. A small quantity of rubbish was present and the rest was composed of seeds found in 15 stomachs. None of those taken are of much importance, and they must be considered unaccustomed food for a bird otherwise insectivorous in its habits.

The following seeds were identified:

Wild fig (<i>Ficus</i> sp.)-----	1	Espino (<i>Xanthoxylum</i> sp.)-----	2
Cenizo (<i>Chenopodium</i> sp.)-----	1	Rubiaceæ sp-----	7
Fresa (<i>Rubus</i> sp.)-----	1		

Summary.—Though considerable numbers of beneficial Hymenoptera and predacious ladybird beetles are eaten by the tody, they are more than counter-balanced by the great numbers of injurious lantern flies, leaf hoppers, beetles, and flies destroyed, and on the whole the bird is markedly beneficial. Its good work is confined largely to coffee plantations, and these fortunately will always furnish it shelter and protection. With encouragement it might in time come into the more open citrus groves, but at present it is largely limited to their borders. It should be given absolute protection in all localities.

BELTED KINGFISHER. *Ceryle alcyon alcyon* (Linnaeus).

MARTIN PESCADOR, PITIRRE DE MANGLE, MATRACA, FRAILE MIGUELETE.

The belted kingfisher is a common winter resident near the coast, about lagoons and bays and along the larger rivers. It does not commonly go far inland, though one was seen along the Rio Caguitos near Caguas on January 10. Gundlach (1878, p. 218) records it as arriving from the north in September,

and the last one I noted on Culebra was on April 21. The bird feeds on small fish, crawfish, etc., and occasionally one was noted about dry open spaces bordered with mangroves, where it was probably seeking small crabs. It occurs singly and is rather wild.

Food.—Of three stomachs examined one was entirely empty. The other two were taken at Mameyes in February, and in one were found remains of a crawfish, while the other bird had eaten a short chunky fish $3\frac{1}{4}$ inches long, seemingly too large for so small a bird to swallow. Under present conditions the kingfisher can not be considered as directly injurious and should be protected.

PORTO RICAN SHORT-EARED OWL. *Asio portoricensis* Ridgway.
MUCARO REAL, MUCARO DE SABANA, MUCARO DE MELON, CORUJA, LLORONA.

The Porto Rican short-eared owl is found only on the island for which it is named, and at present is almost extinct. Natives reported it as occurring at rare intervals in the grass fields of the lowlands at Rio Piedras, and it was also heard of among the lower foothills above Mameyes, near Salinas, Utuado, and Lares, where it was found in almost impassable growths of creepers and tree ferns. Near Utuado it was said to live and nest in small caves on the steepest hillsides, coming out only at night. One was said to have been captured there in the early summer (1912). Near Lares the natives believe that at night these owls swoop down upon an unsuspecting pedestrian, seize his hat, and carry it off into the "malessa" for a nest. This bird is no longer present in sufficient numbers to be of economic importance, and being a terrestrial species, its decrease must be laid to the mongoose. This species certainly has not been common within recent times, as Gundlach (1878, p. 165) did not see it in the seventies when he was on the island. He reports it from Toa Baja, Furnias, and Lares.

BARE-LEGGED OWL. *Gymnasio nudipes nudipes* (Daudin). (PLATES V and VI.)
MUCARO.

The little bare-legged owl is fairly common over the island of Porto Rico, but from its nocturnal habits may be easily overlooked. It was found most often in the coffee plantations in the hills, but was seen on the coast near Mameyes, and was reported from other localities. On the south coast it does not appear to be common.

During the day the birds roost in thick clumps of leaves, and are rather stupid, so that the natives frequently catch them by slipping a noose about the neck. The flight is swift and noiseless. Early in the evening their call is frequently heard, low and tremulous like that of a screech owl. It is given most often from November to May. When the bird is frightened or excited, its note is a loud *boo boo* like that of a burrowing owl. The small birds of the forest often discover this owl hiding in the leaves, and make a great fuss, but the owl remains motionless until they become tired and leave it. Near Maricao one flew out from a hole in a tree attracted by the calling of a wing-tipped vireo, and sat on a limb peering about until it was collected. From this hollow a young bird a week old covered with grayish white down was taken. The nest was a damp cavity, 6 or 8 inches deep, with two or three epiphytes growing before the entrance. May and June would seem to be the breeding months, as other young birds almost fully fledged were taken at Lares during June.

At Lares three were purchased alive, one of which was kept in captivity for four days, the others for a shorter period. The first was a peaceable little fellow, and allowed himself to be handled, stroked, or carried without attempting to bite or scratch, and stared about with big eyes, as though in constant

wonder. On the second day of his captivity two more mucaros were secured, an adult female and a young bird, fully feathered. The young bird was introduced into the cage first, and the earlier occupant objected vigorously with sharp, barking notes, glaring down at the frightened intruder, which cowered in a corner. When the other adult was put in, however, it was too much, and the original bird, grasping it with one foot, began pulling out feathers with claws and bill while the stranger was too startled and dazed to attempt to defend itself. These birds were kept in a darkened room and were quite active during the day.

While the natives claim that the little owl does much damage to the coffee crop by biting the ripened berries, sucking the juices from the sweet inner skin, and then letting the berry fall, most of them admitted upon close questioning that no one had seen the birds doing this. The only known facts seem to be that the owls are heard calling in the coffee plantations at night, and in the morning the berries are found on the ground. The better-informed growers attribute the damage to rats, probably the real culprits. The matter was tested with the captive birds, and though it was only the latter part of June, enough ripened berries were found for the purpose. These were carefully counted and inspected, and for two days the first bird was offered nothing but coffee berries and water. At the end of this time the berries remained untouched, though the bird drank freely, and hunger made it very restless and active. It was then offered a large green grasshopper and a honey creeper. The former was swallowed at once, while the bird was carefully plucked, a process consuming 20 minutes, and then pulled apart and swallowed. For another period of two days the bird was given nothing but coffee berries and water, with the same result. Similar experiments with the other birds produced similar results. These experiments would seem to show that these individuals at least had no taste for coffee. In other localities, as at Mameyes, these owls were accused also of eating gonduros (*Cajanus cajan*), a species of legume, but without proof of any kind. The damage in this case was probably also due to rats.

Food.—Only five stomachs of the little bare-legged owl are available for examination, but the results are interesting. The food, as might be expected, is entirely animal. Orthoptera (14 per cent) comprises roaches, crickets, grasshoppers, and one mantis. One stomach examined was filled entirely with roaches, but this was not used in tabulation, as it was obtained from a native, and among the natives it is common to keep these birds in houses, where they feed extensively on roaches. One bird had eaten a mole cricket (*Scapteriscus didactylus*), a food which at night should be easily found by owls. Caculos or May beetles (*Lachnosterna* sp.), so destructive in many localities, were found in three of the five stomachs and amount to 24.4 per cent. One bird had eaten eight of them. Feeding at night, the little owl is peculiarly adapted to secure them, and with its capacious stomach can destroy large numbers. Cane weevil root-borers (*Diaprepes spengleri*) were found in two stomachs and amount to 1.8 per cent. Other snout beetles, mainly scarred-nosed weevils (*Otiorhynchidæ*), amount to 1.2 per cent, and miscellaneous beetles, longicorns, click beetles, and dung beetles form 8.4 per cent. Lepidoptera (7.8 per cent) are represented by a caterpillar eaten by one bird and moths taken by two. Lizards (10.8 per cent) were eaten by four birds, and evidence keen sight on the part of the owl. In two stomachs were found birds (17 per cent), one of which was a redstart (*Setophaga ruticilla*) and the other a Carib grassquit (*Tiaris b. omissa*). Miscellaneous animal matter (14.5 per cent) was composed largely of scorpions, which were swallowed, sting and all, and odd fragments of Hemiptera, none of them of much importance.



B2130-41

BARE-LEGGED OWL, OR MÚCARO (*GYMNASIO NUDIPES NUDIPES*).



B603:M

STOMACH CONTENTS OF A BARE-LEGGED OWL, OR MÚCARO (GYMNASIO NUDIPES NUDIPES.)

The food of one múcaro consisted of 11 May beetles (*Lachnosterna* sp.) besides other insects and lizards shown in the two lower piles of fragments.

No trace of coffee, or, in fact, any vegetable matter, was found, thus confirming the results of the experiments detailed above. In the light of these data the mucaro must be held guiltless of injury in the coffee fincas. That these owls eat coffee berries appears like many other beliefs to be more tradition than anything else, and even some of the gíbaros (hill people) admit that the belief has no foundation in fact, as is witnessed by a stanza in one of their songs.¹

Though to a certain extent destructive to other birds, the fact that the bare-legged owl feeds so largely on May beetles and injurious weevils places it in the category of beneficial species. As an enemy of the caculo (*Lachnosterna* sp.) alone it merits full protection and conservation.

The following were identified in the stomachs examined:

ORTHOPTERA.		COLEOPTERA—continued.	
<i>Epilampra</i> sp.-----	1	<i>Leptostylus</i> sp.-----	1
<i>Anurogryllus muticus</i> -----	1	<i>Lachnopus</i> sp.-----	1
<i>Scapteriscus didactylus</i> -----	1	<i>Diaprepes spengleri</i> -----	2
HEMIPTERA.		ARACHNIDA.	
<i>Proarno hilaris</i> -----	1	<i>Centrurus</i> sp.-----	1
COLEOPTERA.		<i>Isometrus maculatus</i> -----	1
<i>Pyrophorus luminosus</i> -----	2	VERTEBRATA.	
<i>Parandra</i> sp.-----	1	<i>Anolis</i> sp.-----	4
<i>Atenius stercorator</i> -----	1	<i>Setophaga ruticilla</i> (redstart)-----	1
<i>Lachnosterna</i> sp.-----	4	<i>Tiaris</i> <i>b. omissa</i> (Carib grassquit)-----	1
<i>Compsa</i> sp.-----	1		

CHUCK-WILL'S-WIDOW. *Antrostomus carolinensis* (Gmelin).

CAPACHO, GUABAIRO.

The last of December I saw a chuck-will's-widow in a small second-growth forest above the experiment station at Rio Piedras, and on January 11 Señor José J. Monclova, of that town, gave me a fine specimen. These birds are apparently rare but regular winter visitants to this region. Bowdish (1902-3, p. 365) records them from Vieques Island, December 15 and 28, 1899, and Gundlach (1878, p. 201) had one from Coamo Springs, and one from Arecibo in February, 1876. Stahl (1883, p. 61) says that they are very rare migrants.

Food.—The stomach of the single bird noted above was entirely filled with animal matter. The only thing that could be identified was a May beetle (*Lachnosterna* sp.), amounting to 15 per cent. From what is known of its habits in the North this species should feed on all of the common nocturnal beetles and moths.

WHIP-POOR-WILL. *Antrostomus vociferus vociferus* (Wilson).

GUABAIRO CHICO, GUABAIRO.

The only known species of the whip-poor-will from the island is a female taken by Clark P. Streater for Cory (1889, p. 276). I flushed a bird from a stump in the small forest above the experiment station at Rio Piedras December 23, 1911, and felt certain it was of this species. It is a very rare migrant.

CUBAN NIGHTHAWK. *Chordeiles virginianus minor* (Cabanis).

CREGUETE, CAPACHO, QUEREQUETEC, COMPACHO.

According to Stahl (1887, p. 451), the Cuban nighthawk is a rare summer visitant, arriving in April and leaving in October, and nesting on the island.

¹Abre mucaro los ojos;
Otro pajarito te engano.
Otro espipita el café,
Y tu trapao en la rama!

In his list of birds published in 1883 Stahl simply remarks (p. 61) that it is a migrant. Gundlach (1878a, p. 172) saw the species flying at Vega Baja, Dorado, and Bayamon; and Bello secured one at Mayagüez. Dr. C. W. Richmond (MS.) examined a specimen from the Stahl collection in San Juan in 1900. Sundevall (1869, p. 600) lists one in the collection sent by Hjalmarsen. I did not see or hear of this bird.

GILT-CRESTED HUMMINGBIRD. *Microlyssa exilis exilis* (Gmelin).
ZUMBADOR.

The beautiful gilt-crested hummingbird was fairly common on Vieques Island March 16 to April 3 and one was taken on Culebra April 12. Sundevall (1869, p. 600) has recorded the species from Porto Rico, but according to Gundlach (1878, p. 224) specimens received from Hjalmarsen are of uncertain origin and may possibly have come from St. Bartholomew. Hjalmarsen himself was uncertain as to the exact locality.

Food.—In seven stomachs examined, animal food amounted to 100 per cent. Small homopterous remains which were found in one stomach made up 14.29 per cent, and flies in another, 5 per cent. Hymenoptera, among which were many fragments of ants as well as small parasitic species, were found in three stomachs and amounted to 26.42 per cent. Remains of small spiders (*Oxyopes* sp. and others) constituted 54.29 per cent. The small Homoptera taken are all injurious, but the parasitic Hymenoptera are beneficial. It was impossible, however, to determine just which of the hymenopterous insects were actually predacious and which were tiny flower-loving wasps and bees of no economic importance. The spiders, though predacious, can do as much harm as good, so that this hummer may be considered of no great economic importance but worthy of preservation because of its small size and beauty.

[RUBY-THROATED HUMMINGBIRD. *Archilochis colubris* (Linnæus).
ZUMBADOR.

Gundlach includes the ruby-throated hummingbird in his list, from a picture seen in Bello's album, but there is no other record. He mentions (1878, p. 226) a hummingbird sent him by Blanco in 1868 that resembled the female of this species, but had a tail like that of "Lampornis" (*Anthracothonax*). There is no certain basis for including it among the birds of Porto Rico.]

PORTO RICAN EMERALD, FORK-TAILED HUMMINGBIRD. *Chlorostilbon maugæi* (Audebert and Vieillot).
ZUMBADOR, ZUMZUM, COLIBRI, ZUMBADORCITO.

The small fork-tailed hummer is mainly a species of the coffee plantations in high altitudes, though on the dry south side of the island it ranges to the coast. These birds were frequently observed searching over and under the limbs of the trees and about the leaves and twigs of the coffee. They were seen in the coastal region at Manati only, on the north coast, and not again until Salinas was reached. In the eastern portion of the island they were found only on El Yunque, where they occurred sparingly up to 2,500 feet elevation, and were not seen again in the eastern portion until one was noted above Cayey. They are most abundant on the western end of the island from Aibonito west. Preferring deep shade, they use low perches in coffee trees, only going up to perch on dead limbs in the sun on cool, damp mornings. Their humming was heard many times when the birds themselves could not be located. On shaded slopes high in the mountains they sometimes fed in the open, among the low bushes. They are very pugnacious and pursue each other with sharp, squeaking notes.

The breeding season begins apparently the first of February, and full-grown young were common near Lares in June. The adults molt in May and June,

and regain the full plumage by the first of August. The two long outer tail feathers in the male are very loosely affixed and easily lost. In young males the flesh-colored base of the mandible is less sharply defined anteriorly than in adults.

Food.—In 35 stomachs examined, representing the period from January to August, nothing but animal food (100 per cent) was found. In 5 stomachs were bits of sand and earth, forming considerable bulk in one or two cases. Lantern flies (*Fulgoridæ*) amount to 21.64 per cent, and other small homopteran remains, largely made up of the same forms but so badly broken as to be indeterminate, come to 12.76 per cent. Diptera were commonly eaten and amount to 15.64 per cent, and among the flies taken one mosquito was identified. Hymenoptera (6.28 per cent) were found in 9 stomachs. Small spiders, many of them immature specimens, were eaten constantly and form the largest single item in the food, 43.5 per cent. A little indeterminate animal matter comprises 0.18 per cent.

In consuming large numbers of small Homoptera, all injurious species, this tiny hummingbird does good work in coffee plantations, and, disregarding the spiders, the only beneficial insects in its food were the few Hymenoptera. As these are greatly outweighed by the injurious species destroyed, the bird may be considered beneficial.

The following were identified in these stomachs:

HOMOPTERA.		ARACHNIDA.	
<i>Ormenis</i> sp-----	3	<i>Leucage</i> sp-----	1
DIPTERA.		<i>Epeira</i> sp-----	2
<i>Scatopse</i> sp-----	1		
<i>Agromyza</i> sp-----	1		
<i>Psilopus</i> sp-----	4		

GREEN CARIB, BLUE-BREADED HUMMINGBIRD. *Sericotes holosericeus holosericeus* (Linnæus).

ZUMBADOR.

The large blue-breasted hummingbird was common on Vieques, Culebra, and Culebrita Islands. Hjalmarson had two in his collection taken at Manati and Vega Baja (Gundlach, 1878a, p. 160), and these are the only records for Porto Rico itself. On Vieques it frequented the small areas of forest, and on Culebra was found in the mangroves about the bays. Although of swift flight, this bird does not seem so active as the other hummers, for while feeding it clung to flowers or twigs with its feet, or when this was impossible stopped frequently to rest.

Food.—The food of this hummer, as shown by 22 stomachs taken in March and April, was entirely animal. Small bits of vegetable rubbish were present in two cases, but amount to only 0.33 per cent. Small Homoptera, largely lantern flies (*Fulgoridæ*), and a few leaf hoppers, amount to 14.83 per cent. Anobiid beetles (*Catorama* sp.) of no particular importance were eaten twice, and these with one small weevil make up 0.83 per cent. Flies were commonly eaten and come to 7.14 per cent. Minute Hymenoptera, however, form the great bulk of the food and figure as 64.63 per cent, while small spiders come to 11.31 per cent. The balance (1.07 per cent) was composed of miscellaneous animal matter. Although large numbers of small Hymenoptera are eaten, it is possible that only a part are parasitic. All are undoubtedly picked up while searching flowers, and so perhaps are flower-feeding species of no economic value. They were in such condition as to preclude certain identification. These small insects fairly swarm about the blossoming muñecos and gonduros on the dry islands and offer an abundant food supply. This hummer, like the gilt-crested species, may be

considered neutral until more is learned of the life histories and habits of the smaller little-known tropical Hymenoptera. In consuming numbers of injurious Homoptera it does a certain amount of good and in the destruction of flies it is likewise useful.

The following were identified in the stomachs examined:

HOMOPTERA.		DIPTERA.	
<i>Tettigonia</i> sp-----	1	<i>Psilopus</i> sp-----	1
COLEOPTERA.		ARACHNIDA.	
<i>Catorama</i> sp-----	2	<i>Gamasius</i> sp-----	1

GREEN MANGO. *Anthracothorax viridis* (Audebert and Vieillot).
ZUMBADOR, ZUMBADOR VERDE.

The hummingbird known as the green mango is confined to Porto Rico, and occurs mainly in the coffee plantations and inland forest growths, living either in the densest growth or in the borders of the woods. Only one was noted on the coast (near Mameyes), but a few were seen at Rio Piedras. In dry areas it was entirely absent, none being seen along the semiarid south side of the island nor in the region between Aguadilla and Camuy. When the forests were wet these birds were inactive until the sun was well up. When several were together they were very alert, pursuing each other and the smaller hummers like a flash. Occasionally in August, near Adjuntas, they gave a series of low twittering notes that might almost be called a song, while sitting quietly on a perch, but the usual note was a sharp squeak. Sometimes in collecting them they were attracted by the muzzle of the gun and hovered above it, advancing, retreating, and following after it.

The birds were gathering nesting material in December, and the 1st of February females were busy collecting the downy seeds of certain plants near Aibonito. On the 3d of February one was seen driving a wood pewee from a tree, and later on pursuing a flycatcher, and as I watched it it flew up and settled on the nest, which was about 40 feet from the ground, saddled on a limb in the top of a tall, slender tree. The nest was not finished, and the bird was busy arranging the lining, twisting around to mold it to her body. Every passing bird or insect was noted and her head was moving constantly. The male perched in the top of the same or neighboring trees, whizzing threateningly at all feathered intruders, large and small, but not coming near the nest. From other observations, the male and female remain together throughout the breeding season. Gundlach (1878, p. 222) speaks of finding fresh eggs in October.

The emajagua hedges (*Paritium tiliaceum*), with their large yellow flowers, were favorite hunting grounds with these hummers, as were the flowers of various trumpet creepers (*Ipomea* sp.). The birds were observed many times working over the trunks and large limbs of trees, apparently gleaning small insects from the crevices of the bark. Frequently when little clouds of gnats gathered in the air above the trees, these large hummers hung with rapidly vibrating wings, changing to one side or the other, and whirling completely around with the greatest celerity, while picking up the minute insects. When tired they came down to shaded perches, rested a minute, and then flew up again to continue as before. In the tobacco fields at Caguas they were accused of eating tobacco seed, but this hardly seems probable, and at any rate little damage would result. Near Cayey a bird worked over the ripened heads of some grass along a roadside, and though it may have been gathering insects, none were found on the seed heads on close examination.

Food.—In 29 stomachs animal matter amounted to 98.57 per cent and vegetable to 1.43 per cent. Two birds had eaten seeds, and a third a small quantity of vegetable rubbish, so that this undoubtedly is a regular, though small, part of the food. The largest elements in the animal food were small Homoptera, flies, and spiders. Nearly all of the stomachs were well filled with solid material, and, though these birds visit flowers systematically, as do all the other hummers mentioned in this report, large numbers of insects are captured within the corollas, and the part that nectar plays in the food is not so great as is usually believed. Certainly they are hungry for meat, as well as sweets. They undoubtedly regurgitate waste matter, in the form of pellets, from which the nutriment has been digested. Several of these, 2 millimeters long by 1 wide, ready to be expelled, were found on opening the stomachs, and in each case consisted of a firmly compressed pellet containing chitinous fragments of insects and spiders.

Small Homoptera were found in 9 stomachs and amount to 20.66 per cent, of which 16.35 per cent were certainly identified as Fulgoridæ. Engraver beetles (*Platypus* sp.) (7.77 per cent) occur in 7 stomachs. These beetles swarm in many localities but little is known of their habits in Porto Rico. Other Coleoptera, including a leaf beetle, a phalacrid, and a weevil (*Caulophilus* sp.), figure as 2.07 per cent. Diptera were found in 18 stomachs and form 28.47 per cent, while ants amount to 6.77 per cent. Other Hymenoptera, present in only 7 stomachs, represent 5.63 per cent. Spider remains in 11 stomachs come to 27.15 per cent and a single thrips (*Frankliniella insularis*) (0.05 per cent) completes the count. In taking this thysanopteran a hint is given of possibilities in the destruction of noxious species of economic importance. This large hummer can unequivocally be placed with the beneficial species and, though relatively small, does an appreciable amount of good.

The following were found in the stomachs of this hummingbird:

THYSANOPTERA.		DIPTERA.	
<i>Frankliniella insularis</i> -----	1	<i>Psilopus</i> sp-----	5
HOMOPTERA.		<i>Dilophus</i> sp-----	1
<i>Ormenis</i> sp-----	2	ARACHNIDA.	
COLEOPTERA.		<i>Theridula triangularis</i> -----	1
<i>Caulophilus</i> sp-----	1		
<i>Platypus</i> sp-----	7		

PORTO RICAN MANGO. *Anthracothorax aurulentus* (Audebert and Vieillot).
ZUMBADOR, ZUMZUM, COLIBRI, ZUMBADOR DORADO.

A common resident species in the island, the Porto Rican mango frequents open localities, hedges through pastures, and bushy growths on open hillsides. It is the common hummer of the coast region, and though a few were found in the mountains, as near Cayey and Aibonito, they were not common in high altitudes, and were never found in dense forests. On Vieques Island they were the most abundant of humming birds but were rare on Culebra Island. They were very pugnacious, continually chasing each other, or even driving away honey creepers feeding in the same localities. In pastures they fed at the large flowers of the emajagua (*Paritium tiliaceum*), and spent much time in trees, gleaning over the bark, searching the trunks and twigs, and examining them closely. The throat of one taken in a grapefruit grove near Manati was filled with ants. On Vieques Island this species did not mingle with other hummingbirds, and fed largely at the flowers of the molinillo (*Leonotis* sp.). In the small meadows where these plants grew there were always a dozen or so of the hummers buzz-

ing rapidly around, chasing each other back and forth, or probing the flowers. In March the young on Vieques were full grown, but on Porto Rico they appear to nest in May and June. A full-grown young of the year was taken near Ciales July 13.

Food.—Thirty stomachs examined represented the months from January to August, with the exception of June. Animal matter forms 98.57 per cent and vegetable 1.43 per cent, the latter consisting of a large seed of panic grass found in, one stomach. The bulk of the animal food is composed of small Homoptera, Diptera, and Hymenoptera.

Small Homoptera found in 15 stomachs amount to 33.35 per cent, 13.21 per cent being recognized as lantern flies (*Fulgoridæ*). Leaf hoppers (*Jassidæ*) were taken twice. Snout beetles come to 3.26 per cent, and other Coleoptera, death-watch and leaf beetles mainly, to 5.97 per cent. One mosquito was identified. Remains of Diptera, which as a whole amount to 16.93 per cent, occur in 14 stomachs. Hymenoptera amount to 29.81 per cent; ants were found in 5 stomachs and other Hymenoptera in 26. Spiders were eaten seven times and amount to 7.80 per cent, while miscellaneous matter, mainly earwig remains, totals 1.45 per cent.

This large hummer has a rather varied insect fare and, though many Hymenoptera are eaten, they are compensated for by the injurious leaf hoppers, lantern flies, and beetles consumed. Though small, the hummingbirds have their own niche in the economy of life and do an appreciable amount of good. Movement as rapid as theirs requires quick consumption of fuel, and their stomachs, though small, must be filled frequently to keep up with the demand for muscle-building nutriment. In the quantity of small Homoptera eaten, the present species ranks near the warblers, and in the variety of beetles destroyed it exceeds any of the other hummers found in Porto Rico.

The following were identified in these stomachs:

HOMOPTERA.		DIPTERA.	
<i>Ormenis</i> sp.-----	5	<i>Psilopus</i> sp.-----	2
		<i>Conicera aldrichi</i> -----	1
COLEOPTERA.		HYMENOPTERA.	
<i>Loberus</i> sp.-----	1	<i>Solenopsis geminata</i> -----	1
<i>Haptoncus luteolus</i> -----	1	ARACHNIDA.	
<i>Catorama</i> sp.-----	3	<i>Epeira</i> sp.-----	2
<i>Cerotoma</i> sp.-----	1	<i>Epeira theii</i> -----	1

JAMAICAN BLACK SWIFT. *Nephæcetes niger jamaicensis* (Ridgway).

GOLONDRINA, VENCEJO.

The Jamaican black swift is apparently a rare resident species. Gundlach (1878, p. 200) records it from Lares, Quebradillas, and Utuado, and notes young birds from the latter locality. One was hawking about the sugar experiment station at Rio Piedras on December 16, 1911, but the species was not again seen until May 4. On that date near Yabucoa I saw a pair circling swiftly back and forth, high above a pasture. One was shot as it passed overhead, and came tumbling down, its companion following. The latter circled by once or twice like a flash and then disappeared. The bird taken was only winged, and showed a curious semicircular tuft of feathers in front of and above the eye that strongly resembled the facial disk of an owl. This is not noticeable in skins. Single birds were seen three times during the latter part of June about Lares.

Food.—Two stomachs of this swift contain animal matter only, composed mainly of ants, which in one case amount to 91 per cent and in the other to 45 per cent. One species was identified (*Wasmannia auropunctata*), and one bird

had eaten 157 individuals. In one stomach were five small stinkbugs (*Thyanta* sp.) and five flies (*Euxesta* sp.). Beetles were represented by a pea weevil (*Bruchus* sp.) and a sap beetle (*Stelidota* sp.). Several snout beetles (Calandridæ and Curculionidæ, including one *Caulophilus* sp.) and one engraver beetle (*Platypus* sp.) were taken. An unexpected species was a back swimmer (*Plea striola*), an aquatic form rather out of place in a swift's stomach. The black swift is entirely beneficial in its food habits. It is to be regretted that it is not more common, as it is the only member of its family present in Porto Rico.

GRAY KINGBIRD. *Tyrannus dominicensis dominicensis* (Gmelin). (PLATE VII.)
PITIRRE.

The gray kingbird, a common resident species in Porto Rico, frequents open localities and is found through pastures, cultivated fields, and waste lands from the coast to the higher portions of the island, but is not found in forests or coffee plantations. None were seen in the forests on El Yunque, though the bird was common in all the clearings about its base, and only two were noted near Maricao, which is in the heart of the coffee district.

The native name "pitirre" is in imitation of the call note, which is heard constantly when the birds are near, and which at times is lengthened and softened until it might almost be called a song. The flight is direct, moderately fast, and accomplished by rapidly beating wings. The gray kingbird has the reputation among the country people of being the earliest riser among birds. In the daytime it scatters along the slopes and through the fields to feed, but at nightfall gathers in small parties along streams, to roost in the bamboos or in the mangroves surrounding the lagoons. In Caguas, Adjuntas, and a few other places at eventide they were noted coming in to roost in the trees of the plazas. As it grew dusk considerable numbers came flying in, singly or in little groups of four or five. At first they alighted in the tops of rather high, open trees, and from here made sallies after passing insects, abundant in the early twilight, or flew swiftly and rather erratically through the trees, sweeping and diving, apparently merely for the pleasure of it. They were rather silent on these occasions. As it grew darker all retired to low, dense trees to roost.

The nesting season extends from April to July, and during the latter month young are abundant. At all times very pugnacious, pursuing blackbirds, hawks, and other birds, they now become doubly so, resenting all intrusions in their neighborhood. Occasionally they were seen standing on open perches during showers with outspread trembling wings, evidently enjoying the downpour. At times this species is semigregarious, being drawn together by an abundance of food. Birds were frequently observed capturing insects on the wing about high, breezy points in the mountains. Trees loaded with various fruits, as the guaraguou (*Trichilia spondiodes*) or wild fig (*Ficus* sp.), drew large numbers of them. March 6 along the Rio Mameyes, at the base of El Yunque, dozens of these birds came to feed on the fruit of the guaraguou. Seventeen were counted comparatively close together in one small tree. The laurel berries (*Phæbe elongata*) are ravenously eaten, although they are so large that the birds can scarcely swallow them. Where the fruit of the wild fig grows on slender twigs, the kingbird flies out and pulls it off, returning to a perch on the larger limbs to swallow it. Quantities of the berries of the balsamo (*Palicourea crocea*) and camacey (*Miconia racemosa*) also are taken. During August the young birds rely largely upon vegetable food.

A few facts regarding the insect food of this kingbird were learned from field observation. Birds were twice observed eating the caterpillars of a large sphinx moth. These were beaten on a limb, and then the juices were ex-

tracted by working the body through the bill, while only the skin was discarded. Their services in eating these and other caterpillars were recognized, but at Caguas they were said to do some little damage by breaking the leaves of tobacco plants, either with the bill or the wing, in flying down to pick off the caterpillars. In Mayagüez in June a few of these birds were catching insects above the hot, paved streets, and perching on wires and housetops.

Food.—Eighty-nine stomachs of the gray kingbird available for examination were distributed through the 10 months from December to September, and revealed animal food to the extent of 77.56 per cent. The vegetable matter, 22.44 per cent, was considerable for a bird of this family. Many of the insects taken are large, conspicuous species and include weevils and other beetles, numbers of Hymenoptera, and a miscellaneous assortment from other orders. The vegetable matter eaten may be classed as wild fruits, all of them having a more or less pulpy mass surrounding a seed. These are swallowed whole, and when the soft exterior has been removed the hard seeds are regurgitated, no attempt being made to grind them up unless naturally soft. No gravel or sand was present in any of the stomachs examined.

Animal food.—Though mole crickets are popularly supposed to figure largely in the fare of the pitirre, they were discovered in only six stomachs and amount to only 2.36 per cent, while other Orthoptera, a mantis, and a few grasshoppers and locusts, come to 0.95 per cent. Earwigs (Forficulidæ) (4.72 per cent) were eaten eight times. Cicadas were found six times and make 1.97 per cent, while stinkbugs (Pentatomidæ) in nine stomachs come to 2.12 per cent. These evil-smelling insects seem to be eaten regularly, forming the largest bulk in December. Miscellaneous fragments of other bugs (Heteroptera) comprise 0.68 per cent. In 32 stomachs were found remains of adults of the cane root-boring weevil (*Diaprepes spengleri*) (17.19 per cent), and in destroying these weevils the gray kingbird does as much good as if it fed on the same number of changas. With the weevil stalk-borer (*Metamasius hemipterus*) (5.30 per cent) and miscellaneous weevils (1.34 per cent), largely coffee leaf-weevils (*Lachnopus* sp.), the bulk of injurious weevils taken is nearly one-fourth of the yearly food. These weevils, though just beginning to be recognized by agriculturists, are among the most important insects of the island from an economic standpoint and in destroying them a great service is done. In addition to these one bird had eaten a May beetle (*Lachnosterna* sp.) and other birds had taken buprestids (*Acmaodera* sp.) and leaf beetles. The only beneficial beetle eaten was a single ladybird (*Cycloneda limbifer*). Miscellaneous Coleoptera amount to 1.3 per cent.

Among the Hymenoptera, workers of the honeybee (*Apis mellifica*) (2.21 per cent) were identified in five stomachs collected at random in January and February. In 17 stomachs taken in June, largely at Lares about the apiary of Sr. Linares, domesticated bees form 9.12 per cent. This is the only damaging evidence against this bird, but it is greatly discounted by the good in other lines.

Considerable complaint against the gray kingbird arises around apiaries, the principal loss being said to occur during the nuptial flight of the queens, when the latter, from their relatively slow and heavy flight, are readily captured. The great swarms of these insects, passing back and forth to the hives, are an attraction to these insect-feeding birds. They were observed flying in, circling back and forth among the bees, and above the hives, and then alighting near by in dead trees. Wild species of bees of no economic importance amount to 15.28 per cent of the food. In making post-mortem stomach examinations of the birds taken about apiaries it should be borne in mind that wild bees also are relished, as these can not be distinguished from domestic species when discolored by



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GRAY KING BIRD, OR PITIRRE (TYRANNUS DOMINICENSIS DOMINICENSIS).

digestive juices and mixed with other material without the aid of a microscope. Bees other than the honeybee figure largely in the stomachs taken about apiaries, and in the series taken in June amount to 9.35 per cent. Frequently birds taken near the hives, vigorously catching insects in the passing swarms of bees, contained no trace of honeybees, though observation would have led to the inference that their stomachs would be crammed with them. In fact, about as many bees were found in birds killed in fields and pastures as in those collected in the immediate vicinity of the hives. Moreover, as bees were found in but 5 stomachs out of 89, this should not weigh heavily against the bird when present in ordinary numbers, unless it is about at swarming time, when the queens are liable to be picked up.

Other Hymenoptera amount to 11.33 per cent and are composed largely of wasps. Caterpillars in ten stomachs and moths in four make up 4.75 per cent. Lizards, largely anolis, were eaten by four birds and amount to 3.64 per cent. One bird had swallowed an entire lizard $4\frac{1}{2}$ inches long. Miscellaneous food, consisting of spiders eaten three times, ant lions (*Myrmelionidæ*) twice, one fly, and a small quantity of indeterminate matter, amounts to 2.42 per cent.

The following were identified in the stomachs of the gray kingbird:

ORTHOPTERA.		HYMENOPTERA.	
<i>Schistocerca</i> sp.....	1	<i>Tiphia</i> sp.....	2
<i>Callimantis antillarum</i>	1	<i>Elis</i> sp.....	1
<i>Scapteriscus didactylus</i>	6	<i>Pepsis</i> sp.....	4
		<i>Priononyx</i> sp.....	1
HEMIPTERA.		<i>Oxybelus</i> sp.....	1
<i>Proarno</i> sp.....	2	<i>Polistes</i> sp.....	2
<i>Proarno hilaris</i>	3	<i>Polistes canadensis</i>	1
<i>Nezara</i> sp.....	1	<i>Augochlora</i> sp.....	4
<i>Zelus</i> sp.....	2	<i>Campsomeris</i> sp.....	2
<i>Zelus rubidus</i>	1	<i>Campsomeris dorsata</i>	2
COLEOPTERA.		<i>Exomalopsis</i> sp.....	2
<i>Cycloneda limbifer</i>	1	<i>Anthophora krugii</i>	14
<i>Acmæodera</i> sp.....	2	<i>Centris versicolor</i>	1
<i>Lachnosterna</i> sp.....	1	<i>Bombus</i> sp.....	1
<i>Solenoptera</i> sp.....	1	<i>Apis mellifica</i> (worker).....	5
<i>Cryptocephalus</i> sp.....	1		
<i>Coptocycla signifera</i>	1	VERTEBRATA.	
<i>Diaprepes spengleri</i>	32	<i>Anolis</i> sp.....	3
<i>Lachnopus</i> sp.....	3		
<i>Metamasius hemipterus</i>	14		

Vegetable food.—Of the vegetable matter eaten, seeds and fruits comprise 22.06 per cent, while vegetable rubbish amounts to only 0.38 per cent. The berries borne by the royal palm (*Roystonea borinquena*) and other species of the same family are favorites, as are those of the espino (*Xanthoxylum* spp.), a fruit with little pulp and a peculiarly reticulated seed. Seeds of various euphorbias and of plants of the nightshade family are also sought greedily, and one bird had eaten seeds of the Santa Maria (*Lantana* sp.), a pernicious weed not of major importance in Porto Rico though very troublesome under similar conditions in Hawaii. The moral (*Cordia* spp.) was perhaps the favorite, being found in 12 stomachs. The fruits eaten are all wild and none are of commercial importance.

The following seeds were identified in the stomachs examined:

Royal palm (<i>Roystonea borinquena</i>)..	4	Phytolaccaceæ sp.....	1
Palm (<i>Acrista</i> sp.).....	1	Espino (<i>Xanthoxylum</i> sp.).....	5
Palma de Sierra (<i>Acrista monticola</i>)..	1	Espino (<i>Xanthoxylum martinicense</i>)..	1
Wild fig (<i>Ficus</i> sp.).....	2	Euphorbiaceæ sp.....	4
Chenopodaceæ sp.....	1	Croton (<i>Croton</i> sp.).....	1

<i>Jatropha</i> (<i>Jatropha</i> sp.)	2	Boraginaceæ sp.	1
Staff-tree (<i>Rhacoma</i> sp.)	1	Moral (<i>Cordia</i> sp.)	12
Bejuco prieto (<i>Paullinia</i> sp.)	1	Moral (<i>Cordia nitida</i>)	1
Laurel (<i>Phæbe elongata</i>)	1	Nigua (<i>Tournefortia</i> sp.)	1
Camacey (<i>Miconia</i> sp.)	5	Santa Maria (<i>Lantana</i> sp.)	1
Adelia (<i>Adelia</i> sp.)	1	Rubiaceæ sp.	2
Nightshade (<i>Solanum</i> sp.)	4	Balsamo colorado (<i>Hamelia patens</i>)	1
Ajl (<i>Capsicum</i> sp.)	1		

Summary.—Detailed study of the food of the gray kingbird shows it to be beneficial almost without exception. A few honeybees are eaten, but they are more than made up for by the large bulk of injurious weevils, mole crickets, and Hemiptera destroyed. Though not so great an enemy of the changa (*Scapteriscus didactylus*) as has commonly been believed, it accomplishes practically as much good in consuming cane root- and stalk-boring weevils and coffee leaf-weevils.

In the cultivated fields this bird should be encouraged by every means possible because of the good it does in destroying these insect pests. It is always fairly common in citrus groves, and the cane fields furnish favorite feeding grounds, but when the cane grows tall there are few elevated perches from which the bird may watch for insects. The planting of the jobo tree (*Spondias lutea*) at short intervals along fences and roads is recommended, as its rather straggling growth furnishes open perches and the spiny trunk is a bar to would-be nest robbers.

[KINGBIRD. *Tyrannus tyrannus* (Linnæus).

PITIRRE.

The kingbird is recorded by Hartlaub (1847, p. 611) and by Cory (1892, p. 108) without comment. Cory (1886, p. 245) includes Porto Rico in its range with a query, and as no specimens are recorded it is considered best to treat this species as hypothetical.]

PORTO RICAN PETCHARY. *Tolmarchus taylori* (Sclater).

CLERIGO.

The flycatcher known as the petchary is a common resident in Porto Rico and on Vieques Island. Its original home would appear to be in the forests, which formerly covered the island. It is common now through the dense growth of coffee plantations, and in citrus groves having good-sized trees. In the lowlands its habits appear to be changing, and it is scattered through pastures and fields where there are mango trees or clumps of bamboo. Shaded perches are chosen, especially during the heat of the day. The birds are quiet and not easily seen, as they usually perch where they are hidden by clumps of leaves. From these points they fly out after insects, sometimes for considerable distances. They are rather silent, the call note being a loud *pi ti tity*, heard most often in the breeding season. Near Cayey, in January, one was seen bathing by repeatedly darting down to the surface of a pool. These birds are pugnacious, but not so much so as the gray kingbirds.

The breeding season extends from March to June, and after the first of July young birds were common. In the dense forests of El Yunque they were nesting the first week in March, and scolded the crows with harsh notes when the latter alighted above their nests.

Food.—For examination in the laboratory 61 stomachs of the clerigo were available, collected in the months from December to August and in all districts of the island, including Vieques. Animal matter in these forms 76.91 per cent and vegetable 23.09 per cent. Several species of weevils, Hemiptera, Hymenoptera, and tree toads form the large bulk of the animal food. Wild fruits figure somewhat more extensively than in the case of the gray kingbird and are

taken in the same manner. Its food also differs from that of the kingbird mainly in its small consumption of Hymenoptera, with a corresponding increase in the destruction of beetles and vertebrates, these differences in diet resulting from differences in habitat.

Animal food.—Though the mole cricket (*Scapteriscus didactylus*) was found in only 3 stomachs, it amounts to 3.04 per cent. Other Orthoptera, locusts (Acrididæ) in four cases and a cricket in one, make up 2.68 per cent. The largest item in the animal food, 18.47 per cent, is composed of the cane root-boring weevil, present in 29 stomachs. Remains of as many as six were found in a single stomach, though smaller numbers were the rule. One of these weevils forms a comparatively large bulk and usually they are well broken up, apparently before swallowing. The weevil stalk-borer (*Metamasius hemipterus*), another highly injurious species, was eaten three times and amounts to 1.53 per cent. Miscellaneous snout-beetles come to 2.4 per cent and were mainly coffee leaf-weevils (*Lachnopus* spp.). Among miscellaneous beetles (4.06 per cent) diabroticas (*Diabrotica graminea*) occur three times and a leaf beetle (*Cryptocephalus* sp.) twice. Metallic wood-boring beetles, whose larvæ live under the bark of decaying trees, were also well represented. Ladybird beetles (1.53 per cent), predacious species, were identified four times. Ill-smelling squash bugs were eaten 11 times and figure as 3.45 per cent, while Homoptera, largely cicadas, make up 2.47 per cent. Two other bugs, predatory species, taken by two birds amount to only 0.88 per cent. Moths were eaten by four birds and caterpillars by four, and combined these comprise 4.17 per cent of the food.

Though hymenopterous remains were present in 23 stomachs, they amount to only 8.22 per cent. Fragments of bees (2.12 per cent) were identified in four stomachs, none of them belonging to the domestic species, so that this large flycatcher is vindicated of the charges laid against it by owners of bees. While working around the apiary of Sr. Linares, at Lares, a number of clerigos were taken and their stomachs preserved. They did not come directly into the bee yard, as did the gray kingbirds, but remained in the trees around its border. Swarms of bees were continually passing and repassing, and the flycatchers were seen darting up among them and snapping up unlucky insects time after time. On examining the stomachs of these birds carefully, however, no honey-bees were found, the gizzards being filled with the customary food of the bird. It has been said that the birds do not swallow bees, but work them through the bill to extract the juices of the body and then discard the rest. In extended observations, however, I saw nothing of this, and in the well-known feeding habits of the bird there is nothing to indicate that this is true. When a bird preys upon the vicious social wasp (*Polistes* sp.), individuals of which were identified in four stomachs, there is no reason to suppose that it would reject the body of the weaker honeybee because of its sting.

The little tree toad (*Eleutherodactylus* sp.) had been eaten by 10 of the petcharies examined and forms 8.81 per cent of the total food for the period under discussion. As this flycatcher perches constantly among the leaves and limbs of living trees, these small batrachians are often seen and devoured. Lizards (10.47 per cent), all anolis, were eaten by 18 birds. In consuming these vertebrates a small amount of harm is done, but this counts for little when the good accomplished in other directions is considered. One bird taken in a mangrove swamp at Mameyes had eaten a fiddler crab (*Uca pugnax rapax*), and the stomach of another contained bits of mollusk shell. These, with a small quantity of animal matter which could not be determined, amount to 4.73 per cent.

The following were identified in the petchary stomachs examined:

CRUSTACEA.		COLEOPTERA—continued.	
<i>Uca pugnax rapax</i> -----	1	<i>Cryptocephalus</i> sp-----	2
ORTHOPTERA.		<i>Diabrotica graminea</i> -----	3
<i>Schistocerca columbiana</i> -----	1	<i>Lachnopus</i> sp-----	4
<i>Scapteriscus didactylus</i> -----	3	<i>Diaprepes spengleri</i> -----	29
		<i>Metamasius hemipterus</i> -----	3
HEMIPTERA.		HYMENOPTERA.	
<i>Proarno hilaris</i> -----	1	<i>Polistes</i> sp-----	4
<i>Rocconota</i> sp-----	1	<i>Campsomeris</i> sp-----	1
<i>Zelus</i> sp-----	1	<i>Campsomeris dorsata</i> -----	1
<i>Nezara</i> sp-----	1	<i>Odynerus</i> sp-----	1
		<i>Odontomachus hematoda</i> -----	1
COLEOPTERA.		VERTEBRATA.	
<i>Coccinella</i> sp-----	3	<i>Eleutherodactylus</i> sp-----	10
<i>Cycloneda limbifer</i> -----	1	<i>Anolis</i> sp-----	17
<i>Chrysobothris denticulata</i> -----	1	<i>Anolis stratulus</i> -----	1
<i>Acmæodera</i> sp-----	3		
<i>Photinus</i> sp-----	1		

Vegetable food.—Vegetable matter that may be classed as rubbish amounted to 1.96 per cent, and seeds forming 21.13 per cent were found in 36 stomachs, or a little more than half those examined. Not so many species are eaten as in the case of the gray kingbird and some of the favored species taken by that bird are missing in the appended list, notably the moral (*Cordia*). Berries of palms and the fruit of the wild fig and espino (*Xanthoxylum* sp.) were well represented, while the others were scattering. None were of the least commercial value except possibly the concombres (*Cucumis* sp.), which everywhere in the island grows in a wild state. As in the case of the gray kingbird, no gravel was found in the stomachs examined.

The following seeds were identified in these stomachs:

Arecaceæ sp-----	1	Adelia (<i>Adelia</i> sp.)-----	1
Palmo real (<i>Roystonea borinquena</i>)--	2	Nightshade (<i>Solanum</i> sp.)-----	1
Wild fig (<i>Ficus</i> sp.)-----	3	Santa Maria (<i>Lantana</i> sp.)-----	1
Chenopodaceæ sp-----	3	Rubiaceæ sp-----	2
Almendrillo (<i>Prunus</i> sp.)-----	1	Camacey (<i>Miconia</i> sp.)-----	1
Espino (<i>Xanthoxylum</i> sp.)-----	4	Concombre (<i>Cucumis</i> sp.)-----	1
Bejuco prieto (<i>Paullinia pinnata</i>)----	3	Compositæ sp-----	1

Summary.—The Porto Rican petchary or clerigo is a beneficial species in the true sense and renders great assistance in suppressing numbers of injurious insects. Although a few predacious coccinellids and larger numbers of lizards and tree toads are eaten, the weevils, bugs, miscellaneous beetles, changas, and other Orthoptera destroyed show a large balance in favor of the bird. The bird has been accused of damage by owners of apiaries who believe that it eats many bees. This charge, however, is entirely unsubstantiated, though a number of birds were collected in the immediate vicinity of bee yards. In an island where large insectivorous birds are few this bird is one of the most beneficial of the native species and should be protected by all. The good that it does is not limited to the coffee plantations, in which it chiefly resides, as many of the weevils taken are serious pests in cane fields and elsewhere. The bird is beginning to appear in the more open cultivated lowlands, and if undisturbed in its chosen haunts in bamboos and mango trees should increase in numbers. Further plantings would tend to encourage it in the pastures.

ANTILLEAN FLYCATCHER. *Myiarchus antillarum* (Bryant).

JUI.

The Antillean flycatcher is a common resident on Porto Rico and Vieques, being evenly distributed but nowhere abundant. On April 6 and 20 their unmistakable notes were heard in the dense thorny forest growth on Punto Soldado, Culebra Island. As they have not previously been recorded from this island it is unfortunate that no specimens were secured. The birds are found in coffee plantations, in small patches of second growth along hedgerows, brush-filled ravines, or, where cover is near, even along the borders of cane fields. On El Yunque they occurred up to 1,800 feet altitude. In their habits they are very quiet and unassuming and may easily be overlooked. An open perch is usually chosen from which the birds may watch for insects, as in a small opening in the forest or along the border of a coffee plantation, though the perch is often in the dense leaves in the tops of trees. Insects are captured on the wing, and berries are occasionally eaten. In general appearance, habits, and notes the birds markedly resemble the western wood pewee. During the latter part of April and May birds were seen inspecting nesting holes, though no nests were found. July 5, along the Rio Guajataca, near Quebradillas, a party of three young, just out of the nest, was observed, and after this date young were common. Near Bayamon they were found in the citrus groves. By the superstitious countryman the note of the jui is regarded as the forerunner of news, and whether this be good or bad the bird gets the credit for it.

Food.—In 40 stomachs of the Antillean flycatcher, representing the months from December to August, animal food forms 84.17 per cent and vegetable 15.83 per cent. Hemiptera, weevils, and caterpillars comprise the bulk of the animal food with Hymenoptera in lesser quantities. The vegetable food, less in amount than in the two birds last described (*Tyrannus d. dominicensis* and *Tolmarchus taylori*), is composed mainly of seeds of wild fruits or berries.

Animal food.—Fragments of the mole cricket (*Scapteriscus didactylus*) (1.27 per cent) were found in three stomachs. As the birds are found occasionally watching for prey from low perches bordering the woodlands or even near cane fields, they have opportunity to destroy numbers of the changa. Other orthopteran remains (3.97 per cent) were found in seven stomachs. Grasshoppers and locusts are represented, and odd long-bodied walking sticks (Phasmidæ) were eaten twice. Homoptera, largely cicadas (*Proarno hilaris*), with a few fulgorids, figure as 7.67 per cent, and stinkbugs in six stomachs come to 2.33 per cent. Other bugs (all Heteroptera) amount to 2.62 per cent.

Among beetles, the longicorns in 11 stomachs make up 1.7 per cent, and leaf beetles (Chrysomelidæ) eaten by the same number of birds amount to 1.4 per cent. Among these are diabroticas and a corn leaf-eating beetle (*Myochrous* sp.). Another small chrysomelid (*Cryptocephalus* sp.) was found in six stomachs. The cane root-boring weevil, though represented in only five stomachs, amounts to 11.22 per cent. Other scarred-snout beetles, which were largely made up of the coffee leaf-weevil (*Lachnopus* sp.), identified seven times, come to 5 per cent. Additional weevil remains make up 3.09 per cent. Miscellaneous Coleoptera (1.04 per cent) include a bean weevil (*Zabrotes* sp.) and several darkling beetles (*Helops* sp.). Caterpillars, represented in 14 stomachs, and a few fragments of adult Lepidoptera together comprise 25.85 per cent. Diptera (1.45 per cent), almost entirely disregarded by the gray kingbird and petchary, were recognized in five stomachs.

Hymenoptera (10.51 per cent), a constant element in the food, were found in 20 stomachs, or half those examined. Individuals of wild bees occurred five times, but there was no trace of the domestic species. Wasp remains were

found in three, an ant in one, and in another a small hymenopteran parasitic on ants (*Kapala* sp.). Less than half those consumed can be called beneficial.

One bird had eaten a lizard and one a tree toad, together forming 1.07 per cent. Snails were found in two stomachs, a dragon fly in one, a neuropteran in one, and some insect eggs in another. These miscellaneous items total 3.98 per cent.

The following were identified in the stomachs examined:

ORTHOPTERA.		COLEOPTERA—continued.	
<i>Neoconocephalus</i> sp.-----	1	<i>Helops</i> sp.-----	4
<i>Scapteriscus didactylus</i> -----	3	<i>Lachnopus</i> sp.-----	7
HEMIPTERA.		<i>Diaprepes spengleri</i> -----	5
<i>Proarno</i> sp.-----	1	HYMENOPTERA.	
<i>Proarno hilaris</i> -----	4	<i>Kapala</i> sp.-----	1
<i>Ormenis</i> sp.-----	1	<i>Exomalopsis</i> sp.-----	1
<i>Nezara</i> sp.-----	1	<i>Polistes</i> sp.-----	2
<i>Thyanta</i> sp.-----	1	<i>Elis sexcincta</i> -----	1
COLEOPTERA.		MOLLUSCA.	
<i>Acmæodera</i> sp.-----	1	<i>Subulina</i> sp.-----	1
<i>Eburia</i> sp.-----	1	VERTEBRATA.	
<i>Compsa</i> sp.-----	2	<i>Eleutherodactylus</i> sp.-----	1
<i>Leptostylus</i> sp.-----	2	<i>Anolis</i> sp.-----	1
<i>Cryptocephalus</i> sp.-----	6		
<i>Myochrous</i> sp.-----	1		
<i>Diabrotica</i> sp.-----	2		
<i>Zabrotes</i> sp.-----	1		

Vegetable food.—Of the vegetable food 1.94 per cent may be called rubbish and the remainder, 13.89 per cent, is composed of seeds, usually with a little of their pulpy exterior accompanying them. One bird had eaten 36 grass seeds (*Paspalum* sp.), but this is apparently an unusual food. The espino (*Xanthoxylum* sp.), a favorite, was found seven times. Others recognized were the moral (*Cordia* sp.), nightshade (*Solanum* sp.), and wild fig (*Ficus* sp.).

The seeds in the following list were identified in the stomachs examined:

<i>Paspalum</i> (<i>Paspalum</i> sp.)-----	1	Espino (<i>Xanthoxylum</i> sp.)-----	7
Wild fig (<i>Ficus</i> sp.)-----	1	Nightshade (<i>Solanum</i> sp.)-----	2
<i>Chenopodaceæ</i> sp.-----	2	Moral (<i>Cordia</i> sp.)-----	2
Vetch (<i>Vicia</i> sp.)-----	2		

Summary.—The vegetable food of the jui may be dismissed with the statement that it is composed of wild species of no importance to man. In the animal matter, Hymenoptera, the large family containing wasps, bees, and many parasitic species, stand out rather prominently, but as more than half of those taken are known to be neutral, their destruction is of little importance. The vertebrates destroyed are of value to man, as they aid in the war on insects. Some of the predatory bugs may also be considered beneficial. These, however, though long in enumeration are small in bulk compared with the great mass of destructive weevils, beetles, squash bugs, and others forming the average daily food of the Antillean flycatcher. Only one-eighth of the animal food may be considered more or less indirectly beneficial to man and agriculture, and the remaining seven-eighths consists almost entirely of animals living contrary to human interests. Thus this species is a firm ally of agricultural interests in Porto Rico. Though retiring in habit, it is more common than is supposed by the casual observer and its whistled call note, regarded with superstition by the country laborer, may always be considered an omen of good fortune.

PORTO RICAN WOOD PEWEE. *Blacicus blancoi* Cabanis.
BOBITO, JUL, JUL PEQUEÑO.

The bobito, or wood pewee, is a tolerably common resident species in the western portion of Porto Rico. It is not recorded from the eastern half of the island beyond a line passing through Salinas, Aibonito, and Ciales. This bird frequents coffee plantations, small patches of second growth, or on the south coast the dry brushy pastures, but very few even of the country people are familiar with it, as it is so inconspicuous that it would be overlooked by one not acquainted with its habits. In the coffee plantations it is found on the slopes about the heads of small gullies, or on the middle portion of long, steep slopes. It usually selects open perches on dead limbs not far from the ground, from which it makes short sallies after insects. The call note of the males, a low tremulous *pree-e-e-e* given at times, with trembling wings, can not be heard more than a hundred yards, and is so ventriloquial that neither its direction nor the distance from which it comes can be determined. Frequently a bird will call from a perch not 30 feet away for several minutes before it is seen, so still does it sit and so well do its colors harmonize with the background. The females are silent, usually appearing suddenly on a limb, and without doubt are often overlooked. The breeding season is in May, though no nests were found, and in July and August the birds were molting badly. Near Cabo Rojo they were found in the mangroves bordering the seacoast lagoons, but nowhere else did they approach so close to the ocean.

Food.—The Porto Rican wood pewee is a true flycatcher, as in 29 stomachs taken in February, May, June, and August 99.17 per cent of the contents was animal matter and 0.83 per cent vegetable. The vegetable matter was contained in a single stomach taken May 1, 1912, near Salinas, and consisted of seeds of the espino (*Xanthoxylum* sp.). Of the animal food, Diptera and Hymenoptera form the largest elements, though many beetles are taken. A cricket (*Orocharis* sp.) was found in one stomach and amounts to 0.56 per cent. Homoptera (5.39 per cent) are composed largely of lantern flies and tree hoppers, though one bird had discovered a cicada. Other bugs (Heteroptera), all so broken or fragmentary as to be indeterminate, with the single exception of one stinkbug (Pentatomidæ), were found in three stomachs and amount to 1.45 per cent. Leaf beetles (3.19 per cent) were encountered in 10 stomachs. A small species of uncertain habit (*Cryptocephalus* sp.) was identified six times. Ladybirds (Coccinellidæ) (3.87 per cent) appeared in five stomachs; they are usually predacious species and are the only beneficial beetles taken. Those eaten are all native forms, none of the species recently introduced to combat the mealy bug in cane fields being found. An engraver beetle (*Platypus* sp.) (8.86 per cent) was identified in nine stomachs. These are common about coffee plantations in many localities, and as many as 43 were found in a single stomach. Other weevils, found in nine stomachs, amount to 1.84 per cent, among which was a curculio (*Anthonomus* sp.). Coleoptera not included above come to 2.43 per cent, among which were a water scavenger beetle, click beetles (*Monocrepidius* sp.), several longicorns, darkling beetles, and others. The beetles eaten, though nearly all small, cover a wide range of families and are largely injurious species.

Moths are represented in eight stomachs and a caterpillar in one, together forming 10.87 per cent. The former figure more extensively in the food of this bird than in any of the flycatchers previously mentioned and show that active prey is watched for and captured on the wing, the slower-moving caterpillars being unnoticed.

Of the total food, 23.07 per cent is composed of Hymenoptera, large numbers of which are parasitic species. Representatives of this order were found in

17 of the 29 stomachs examined, and among them fragments of three ichneumon flies and remains of several bees were identified. They are only exceeded in bulk by flies (37.15 per cent), which were eaten constantly and were present in 23 stomachs, in some cases comprising as much as 85 per cent of the bulk. Miscellaneous matter, consisting of a spider, a snail, and an earwig, amounts to 0.49 per cent.

The following insects were identified in the stomachs examined:

ORTHOPTERA.		COLEOPTERA—continued.	
<i>Orocharis</i> sp.....	1	<i>Mordella</i> sp.....	1
		<i>Anthonomus</i> sp.....	1
		<i>Platypus</i> sp.....	9
HEMIPTERA.		DIPTERA.	
<i>Ormenis</i> sp.....	1	<i>Psilopus</i> sp.....	1
<i>Tettigonia</i> sp.....	1	<i>Volucella</i> sp.....	1
		<i>Sarcophaga</i> sp.....	1
COLEOPTERA.		<i>Lucilia</i> sp.....	2
<i>Copelatus</i> sp.....	2	<i>Pyrellia violacea</i>	1
<i>Cycloneda limbifer</i>	3	<i>Euwesta</i> sp.....	1
<i>Scymnus roseicollis</i>	1		
<i>Scymnillus</i> sp.....	1	HYMENOPTERA.	
<i>Monocrepidius</i> sp.....	2	<i>Polistes</i> sp.....	1
<i>Chrysobothris</i> sp.....	2	<i>Exomalopsis</i> sp.....	1
<i>Lema</i> sp.....	1	<i>Halictus</i> sp.....	1
<i>Cryptocephalus</i> sp.....	6		
<i>Zabrotes</i> sp.....	2		
<i>Helops</i> sp.....	1		

Summary.—Though not large enough in body to cope successfully with the larger insect pests of the island, the Porto Rican wood pewee aids effectively in destroying smaller species, some of which are known to be injurious, while others may prove upon investigation to be of more importance than is believed at present. Some harm is done in the destruction of the parasitic Hymenoptera, which are inevitably snapped up by any true flycatcher continually on the watch for winged prey, but these are counterbalanced by injurious species of small Homoptera, moths, weevils, and other beetles as well as the flies destroyed. From its unobtrusive habits this pewee attracts little attention, but should be protected wherever found.

ANTILLEAN ELAINEA. *Elainea martinica martinica* (Linnæus).
RUISEÑOR PEQUEÑO.

The small flycatcher, known as the Antillean elainea, has not previously been recorded from this region, but was found to be tolerably common on the south side of Vieques Island from Porto Ferro east, on Culebra Island, and also on Culebrita Island and Louis Peña (Southwest Cay). It would appear to be a summer visitant, as it was not noted on Vieques until March 25, but after that time it was fairly common. All the birds taken appeared ready to breed. It is a solitary species, individuals being found considerable distances apart, in dense, almost impenetrable thorny growths of cactus and small trees. In habits it combines the characteristics of flycatchers and vireos.

Food.—In 10 stomachs of this species taken in March and April animal food amounts to 14.5 per cent and vegetable to 85.5 per cent.

The only animal food taken at all regularly consisted of spiders (2.4 per cent), found in three stomachs. One bird had eaten a large caterpillar and another two weevils. In one stomach was a leaf beetle (*Cryptocephalus pusio*) and in others bits of an earwig and a ladybird beetle (*Cycloneda limbifer*).

In eating so much vegetable food (85.5 per cent) the elainea differs markedly from our northern flycatchers, none of which approaches it in this respect at any

season. It is very probable, as our knowledge of the food of tropical and sub-tropical forms of this large family increases, that numbers will be found to be almost wholly vegetarian in their diet. Certainly this seems to be the case with the species under discussion. Three stomachs were filled entirely with seeds and drupes and in all but one these formed much the larger share. The seeds of the family of euphorbias were sought for, and a nightshade (*Solanum* sp.) occurred three times. Several species found were indeterminate, but apparently all were eaten for the soft outer covering, the seeds being regurgitated.

The vegetable food of this species is not of importance, and what animal matter is taken is nearly all injurious to agriculture, so that wherever it occurs the elainea may be considered a beneficial species.

[TREE SWALLOW. *Iridoprocne bicolor* (Vieillot).

GOLONDRINA.

Gundlach (1878, p. 199) says that he did not observe the tree swallow in Porto Rico but records it from a picture seen in the album of Bello. Stahl (1883, p. 61), probably following Gundlach, remarks only that it is a rare migrant, so that, without definite specimens on record, it can be included only as a hypothetical species.]

BARN SWALLOW. *Hirundo erythrogastra* Boddaert.

GOLONDRINA.

Of the barn swallow Gundlach (1878, p. 197) says that it arrives from the north in September and passes on southward. A single bird was seen during the present work on February 16 near Punta Picua, north of Mameyes. It would seem to be an irregular visitant during spring and fall migrations. It is a member of a family whose species are entirely beneficial in their habits. During its brief stay on the island, it will probably be found only in the lowlands.

[BANK SWALLOW. *Riparia riparia riparia* Linnæus.

GOLONDRINA RIBERIEGA.

The bank swallow also is recorded by Gundlach (1878, p. 199) on the basis of a picture seen in the album of Bello, and later records are apparently based upon his statement. It may occur as a rare migrant from the United States, but must at present be included only as a hypothetical species.]

JAMAICAN CLIFF SWALLOW. *Petrochelidon fulva pæciloma* (Gosse).

GOLONDRINA, GOLONDRINA DE CUEVAS.

The Jamaican cliff swallow is a common resident species in Porto Rico, being most abundant on the western end of the island. A small number were observed at Humacao, but on the east coast few were noted, and none were seen on the south coast east of Salinas. For the most part confined to the coast region, they were found inland only in the northwestern portion extending from Lares through Utuado to Ciales. This small species occurs ordinarily in small parties, feeding above pastures, lowland meadows, or along the beaches. On the wing it is light and graceful and when feeding the flight is very uncertain, the bird frequently changing its direction. In August little bands of 25 or 30 fed over the lowlands and perched close together in twittering flocks on telephone wires. During heavy rainstorms they seemed to have a hard time keeping up against the downpour, as they continually struggled to rise and were as steadily beaten down. Such storms would, without doubt, prove fatal to birds not long out of the nest, with the flight feathers still soft and undeveloped.

This species breeds in colonies in May and June, and nests on overhanging faces of cliffs or in caves, a practice so universally recognized that "La cueva de las golondrinas" is a common appellation given to caverns in Porto Rico. In these a mud rim, made of pellets carried in the bird's mouth, is thrown up on the

outer edge of small shelves or holes and behind this is placed a felted mass of plant downs from cactus and other plants to receive the eggs. From fragments of shells examined the eggs appear to agree closely with those of *P. lunifrons*, being white, spotted with reddish brown and lilac. North of Aguadilla about 40 pairs were nesting in small caves in cliffs over the ocean, some only 20 feet above the waves. All nests were back in holes, and the birds circled about calling excitedly in a close flock before the entrance, flying up two or three at a time to hover before them for an instant. There must be a great mortality here among the young, as there is no place for them to go on leaving the nest except out over the waves, and it was some distance to safety at the top of the cliffs. East of Lares in "La Cueva Pajita," a grotto 200 feet long and open at both ends, was a colony of about 300 of these swallows, some of them near the entrance, while others had built in so far that in the obscurity the birds could not be distinguished from the large bats that circled about with them. Some of the ledges supporting nests were so narrow that the sitting bird was forced against the wall, greatly abrading the breast feathers. As these abrasions occur only on one side, the bird must always have faced the same way while on the nest; both males and females incubate, as these were observed in specimens of both sexes. About this colony on June 20 immature birds were seen on the wing, following the parents and teasing for food, while others were still nest building. When tired the young birds perched in the leafy tops of trees.

A few of these swallows appear to be changing their nesting habits and method of nest construction by taking advantage of shelters provided by man. Inside the train shed of the Linea Ferrea del Oeste at Bayamon was a small colony building against the rafters, and one pair had built on a beam in the gable of a neighboring hotel. The nests were globular in shape, only two being seen with the long bottle neck found in the nest of *P. lunifrons*, and those two were imperfect. Most of these nests had only a large, roughly circular entrance in the side, and a few were mere platforms of mud, hardly inclosed.

The ordinary note of this swallow is a soft *chu chu*, and the males have a chattering, twittering song given while flying.

Food.—Thirty-six stomachs of this swallow were examined, taken in December and in the five months from April to August. The greater number were secured in the western part of the island. In these, animal food forms the entire content, as might be expected from observing the habits of the bird, vegetable rubbish occurring in one stomach only, and then in such small amount as to be inappreciable. Although true bugs (Hemiptera) and flies form goodly items, the major share of the food is taken from the great army of beetles especially common in tropical and subtropical regions.

Orthopteran remains found in a single stomach taken in July form 1.39 per cent of the total. Lantern flies (Fulgoridæ) in 11 stomachs amount to 3.47 per cent, and small species in allied families, with similar injurious habits, among which may be mentioned jumping plant lice (Psyllidæ), come to 1.08 per cent more. Stinkbugs (Pentatomidæ) occurred 16 times and figure as 7.63 per cent. Most of them were eaten in June, and bugs of this family amount to 22.58 per cent in that month. Bugs of the chinch-bug family (Lygæidæ) and others not determined come to 3.25 per cent.

Among the leaf beetles (Chrysomelidæ), which form 8.06 per cent and which were recognized in 22 stomachs, were the tobacco leaf-beetle (*Epitrix parvula*), found four times; the bean leaf-beetle (*Cerotoma denticornis*), likewise found four times; and a flea beetle (*Systena basalis*), found seven times. Other species were tortoise beetles (*Coptocycla signifera*), which attack the leaves of the sweet potato, and a leaf eater (*Myochrous* sp.). Leaf beetles belonging to the genus *Cryptocephalus* were found in 15 stomachs. Engraver beetles (*Platy-*

pus sp.), eaten by 29 of the birds, amount to 41 per cent of the food for the period under consideration. They are found in the food of all the months represented except December, though in July they amount to only 2.17 per cent. As many as 400 of these beetles were eaten at a single meal, and several birds had taken 200 or over. Near Aguadilla, in June, the swallows were capturing large numbers for their young, carrying them in the back of the mouth and below the tongue in a well-moistened mass. Other snout beetles amount to only 1.19 per cent, but were all small species. Cane shot-hole borers (*Xyleborus* sp.), of considerable damage in cane fields and also known to injure the shade trees of the coffee (*Inga vera* and *I. laurina*), were found in seven stomachs. Few beneficial species were destroyed. Rove beetles (Staphylinidæ), which feed upon decaying vegetable and animal matter, were eaten nine times, and lady-bird beetles four. Together these form but 1.31 per cent, a small amount when compared with the large bulk of snout beetles consumed. Sap-feeding beetles (Nitidulidæ), eaten by eight birds, and water scavenger beetles, detected in five stomachs, together with indeterminate fragments of others, make 4.77 per cent.

Flies (16.07 per cent) were eaten regularly and occur in 20 stomachs; ants in 17 stomachs amount to 9.13 per cent. The latter were taken from clouds of males and females on their mating flights, and the numbers then destroyed mean more than when individual workers are eaten, as each queen may be considered the nucleus of a new colony. Miscellaneous Hymenoptera make up 2.67 per cent. A moth was found in one stomach. The stomachs of two adults contained bits of snail shell and gravel, and the stomach of a nestling taken in a cave contained a rough angular bit of gravel of good size. Very few beneficial insects are taken, the great bulk of the food consisting of directly injurious species. As the birds feed in loose flocks over a large expanse of territory they must exert considerable influence where found, and where insects are abundant they congregate to feed upon them.

From the foregoing it can readily be seen that the cliff swallow is one of the best friends of the agriculturist. Should the bird modify its breeding habits, as it now does in a few places, so as to resort to buildings erected by man rather than to caverns, every encouragement should be offered it and the nests should in no case be molested. Many believe that swallows bring vermin in their nests, but it is firmly established that man's parasites are not borne by our avian friends, and in case of unwelcome visitations the blame must rest elsewhere.

The following insects were identified in the stomachs examined:

[illegible]

CARIBBEAN MARTIN. *Progne dominicensis* (Gmelin).
GOLONDRINA, GOLONDRINA DE IGLESIAS.

The Caribbean martin is a common summer resident in all parts of Porto Rico and occurs also in the island of Vieques. The first were seen at Cayey on January 23, and after this they were common everywhere. On August 16, while on the summit of the range above Adjuntas, martins were heard continually so high overhead that they could not be seen, and occasionally three or four would sweep down over the slopes for a few minutes. These were evidently migrant, as they were working steadily southward, though at this date in some localities martins were still feeding young. Stahl (1887, pp. 450, 451) says that they arrive regularly from the end of January to the first of February, and gives December 23 as the earliest date in eight years' observations. On the wing they are strong and vigorous, sweeping about in large circles, chattering, and calling loudly. The greater number remain close about the towns, perching on wires and roofs of houses, and feeding high overhead. Sometimes parties play about the mouths of lagoons and rivers, frequently darting swiftly down at a boat in the water, and then rising abruptly, only to repeat the performance. On cold rainy days they follow cattle in the pastures for the insects they frighten up, or for flies drawn by them. At Cabo Rojo a parrot in a cage screaming and talking interested the martins greatly. Four or five gathered on a wire above it, peering down, twittering, and lifting the wings nervously until, at some piercing shriek, they left precipitately.

This species was apparently mated when it arrived, and began at once to investigate holes in the church towers and eaves of buildings, with much calling and warbling. In the wilder localities a few sought their ancient nesting sites in hollow trees, though the greater number nest in the towns. Near Mameyes a male was seen disputing with a woodpecker the possession of a hole in a coconut palm, and a number were nesting here in suitable localities. On the estate known as Manantial, north of Guanica, about 30 were nesting in small openings in the sides of an old brick chimney 75 feet high, and birds were found occupying holes in trees near the Hacienda Catalina, and along the Rio Guajataca near Quebradillas. They were observed carrying nesting material as early as the 9th of February, but nest building seemed to be rather a dilatory process, and eggs were apparently not deposited before the 1st of May. The first young seen on the wing were observed at Comerio July 27, but fledglings were still being fed in the eaves of a church at Cabo Rojo the last of August, though apparently some of the earlier nesting birds had left the island. Only one brood seemed to be raised.

Food.—Twelve stomachs of the martin were examined, taken in the months of February and May. These contained animal matter only and usually were well filled. Though this small number can not serve as a true index to the food, it gives an idea of the tastes of the bird. A large number of stinkbugs were taken by nine of the birds, and for the two months amount to 24.17 per cent. Beetles (7.33 per cent) also were present in nine stomachs. Among injurious species were leaf beetles, flea beetles, and a small quantity of weevil remains, while others in the list following are of unknown economic tendencies in the Porto Rican insect fauna. Remains of flies, mainly so badly broken as to be indeterminate, come to 26.42 per cent and Hymenoptera to 33.41 per cent. The great bulk of the latter was wasps, only a few parasitic chalcids being found. Dragon flies (8.09 per cent) in five stomachs are the only beneficial insects taken in quantity. One bird had secured a small cricket (*Ellipes minuta*).

The martin is without doubt a beneficial species and one to be protected. A few parasitic Hymenoptera are consumed and a little more than 8 per cent of the food is made up of dragon flies, which destroy many mosquitoes, but

these are balanced by the larger numbers of stinkbugs and flies eaten, not to mention many beetles. At Maricao, in the first days of June, thousands of the destructive termites or white ants were flying in the evenings and in the dusk a dozen or more martins circled back and forth through them, eating until they were satisfied. These insects feed upon wood and are very destructive, honeycombing the walls and floors of houses, and building enormous nests in the forests with covered passageways leading up the trunks of trees; thus in eating these the martins do good service. Apparently no attempt has been made to provide these birds with artificial nesting boxes, but there is no reason why this plan should not prove successful and permit the species materially to increase in numbers. At present the nesting sites suited to their needs are few.

The following insects were identified in the martin stomachs examined:

ORTHOPTERA.		COLEOPTERA—continued.	
<i>Ellipes minuta</i> -----	1	<i>Cryptocephalus</i> sp-----	1
		<i>Rhipiphorus</i> sp-----	1
HEMIPTERA.		<i>Caulophilus</i> sp-----	1
<i>Thyanta</i> sp-----	1		
<i>Thyanta perditor</i> -----	1	DIPTERA.	
		<i>Eristalis albiceps</i> -----	4
COLEOPTERA.		<i>Compsomyia macellaria</i> -----	2
<i>Tropisternus collaris</i> -----	1		
<i>Hyperaspis apicalis</i> -----	1	HYMENOPTERA.	
<i>Carpophilus hemipterus</i> -----	1	<i>Chalcis</i> sp-----	1

PEARLY-EYED THRASHER. *Margarops fuscatus fuscatus* (Vieillot).
ZORZAL, ZORZAL PARDO, ZORZAL DE LOS PALMARES, ZORZAL NEGRO, TRUCHE.

The pearly-eyed thrasher is a resident species in this region. On the smaller islands it is very common, but shy and usually hard to secure, as it lives in the densest growths of brush, creepers, and cactus. In following the trails I would see one dart across ahead of me or fly up from the ground at one side, to be lost immediately. In habits it is remarkably thrushlike.

These birds are very curious, and were attracted by "squeaking," while the outcries of other birds always drew them. When singing they were easily approached, as with wings and tail hanging they sat on a limb, usually hidden by leaves. The song resembled the syllables *wheur, tel leur, tsee*, given brokenly with many variations, so that, while the notes themselves were pleasing, the whole effect was disconnected and rambling. The birds sing by the hour, and the monotony and persistency of the sounds become in time rather wearisome.

Food.—In 38 stomachs of this large, robust thrasher animal matter amounted to only 12.81 per cent, while vegetable food reached the large sum of 87.19 per cent. The animal food is scattering, being apparently whatever attracts the attention of the bird, nearly all of the insects taken being of large size. One bird collected on Culebra Island April 10 had eaten the nymph of a mole cricket (*Scapteriscus didactylus*). Other orthopteran remains (2.75 per cent) were found in six stomachs and among them may be noted a walking stick (phasmid) and a grasshopper (acridid). Weevils (1.36 per cent), occurring four times, included the cane root-borer (*Diaprepes spengleri*), a curculio, and others. Spiders (2.63 per cent), conspicuous in the fauna of the dry islands where the thrasher is most common, were eaten seven times. Two birds taken in the coast region had captured crustaceans, one of which was a fiddler crab (*Uca pugnax rapax*). The birds were seen a time or two in the mangroves peering down with great interest at the army of crabs marching about beneath them. Vertebrate remains, a tree toad and two lizards (*Anolis* sp.), amount to 1.45 per cent.

Besides these a caterpillar, a stinkbug, two earwigs, an ant, and a neuropterous insect were identified.

The vegetable food is mainly wild fruits or berries, though some of them have but little pulp surrounding the seeds. The seeds are in most cases regurgitated, as no trace of gravel for grinding them up and fitting them for digestion was found, though some were soft enough to be broken up by the stomach alone. Berries of palms were favorites and fruits of various shrubs of the family Rubiaceæ were eagerly sought. The espino (*Xanthoxylum* sp.) and berries of a palm (*Coccothrinax* sp.) were each found five times. A few of the seeds identified (*Hypoxis* sp. and *Sida* sp.) do not come in the category of fruits and berries, but with small quantities of vegetable rubbish may have been taken accidentally. None of the vegetable food consumed has any value to man, while the insects taken, though small in bulk, are of considerable economic importance. Thus the bird may be classed as beneficial. Hunting it for food should be prohibited, both because the bird is useful and because the hunter in pursuit of small birds does not always distinguish between species but kills indiscriminately.

Following is a list of the seeds identified in the stomachs examined :

Palmo (<i>Coccothrinax</i> sp.)-----	5	Adelia (<i>Adelia</i> sp.)-----	2
Palmo real (<i>Roystonea borinquena</i>)--	2	Nightshade (<i>Solanum</i> sp.)-----	2
Star grass (<i>Hypoxis</i> sp.)-----	1	Moral (<i>Cordia</i> sp.)-----	2
Phytolaccaceæ sp.-----	2	Tantillo (<i>Randia aculeata</i>)-----	3
Espino (<i>Xanthoxylum</i> sp.)-----	5	Balsamo colorado (<i>Hamelia patens</i>)--	2
Jatropha (<i>Jatropha</i> sp.)-----	1	Bejuco de berac (<i>Chiocococa alba</i>)----	1
Bejuco prieto (<i>Paullinia pinnata</i>)----	1	Palo moro (<i>Psychotria pinularis</i>)----	2
Escoba (<i>Sida</i> sp.)-----	2		

JAMAICAN MOCKINGBIRD. *Mimus polyglottos orpheus* (Linnæus).

RUISEÑOR, SINSONTE.

In Porto Rico mockingbirds are common residents in the lowlands, only a few being seen above 1,000 feet elevation, though they were found in open pastures at the highest points visited; for example, near Aibonito, and on Mount Pelado above Cayey. They seem to thrive best in a dry climate, and are most abundant along the south coast, while on Vieques they are very common. As usual, these birds frequent the tree-dotted pastures, hedges, and thickets, though near Guanica they are common through the open cane fields, feeding on the ground in newly plowed lands, and following the fences through the cane, where there is no cover whatever. When flushed in the open fields they fly only short distances before dropping back to the ground. They are common also in the citrus groves around Bayamon and Manati.

In pastures and thickets they are shy and secretive, though the males, singing from the top of some tree or bush or flying up a few feet and then dropping back, are a conspicuous feature in the landscape. They sang most from January until July, after which they were silent except for their scolding notes. The nesting season extended from January until June, and after that young were common. In July and August they were molting. Nest building was noticed near Caguas January 5, and young birds a week old were found on Vieques Island April 3. Near Mameyes in February nearly all the birds noted were incubating. One pair here, by their outcries, drew attention to a small owl hidden in the brush.

In all the towns visited mockingbirds were prized as cage birds, and taking the young birds from the nest was a common practice. Usually they were taken when quite young, and their cages hung out in the bushes, where the adults could feed them. Fine singers among the males were valued as high as

\$10 or \$15. In the country one was occasionally seen in a rude cage made of a large calabash, with string laced across the opening to prevent escape.

Food.—In 49 stomachs of the mockingbird animal matter forms 31.21 per cent and vegetable 68.79 per cent. The birds were collected in all the months from December to August save June and are quite evenly distributed through the region under consideration. The smallest quantities of animal matter are found in January and April, 8.5 per cent and 8.14 per cent, respectively. Lepidoptera, largely cutworms, and Orthoptera compose the bulk of the animal matter and the vegetable food is made up of wild fruits and berries. The relative proportions of animal and vegetable food are practically identical with those found by Prof. Beal in the examination of a large series of mockingbirds from California.¹

Animal food.—Five of the mockingbirds examined had eaten mole crickets (*Scapteriscus didactylus*) (3.62 per cent). Mention has been made of this bird's habit of feeding at times in cultivated fields far from its usual cover, and it is undoubtedly during such forays that these injurious insects are captured. Other orthopterous remains in 11 stomachs (4.84 per cent) are less important than the mole cricket, but in capturing them the bird does good service, as all are more or less injurious. The first mockingbird collected, taken at Río Piedras in December, had eaten a cane root-boring weevil (*Diaprepes spengleri*), but this insect was not identified in stomachs subsequently secured. This with other weevils, among which was a coffee leaf-weevil (*Lachnopus* sp.), in four additional stomachs comprise 1.62 per cent. Other beetle remains (2.06 per cent) are all injurious species with the exception of two ground beetles (carabids). Among these others may be mentioned a leaf beetle (*Cerotoma denticornis*) and a tortoise beetle (*Coptocycla signifera*), while one bird had captured two wireworms, the immature form of the click beetle. Remains of Lepidoptera, moths in 2 stomachs and caterpillars in 19, come to 12.4 per cent. The latter in at least five instances were cutworms, several being found in a single stomach. These are destructive wherever found. Hymenoptera, largely ants, form 1.85 per cent. A few chalcid flies in one bird were the only beneficial species identified. Six birds had eaten spiders and one a mite, which amount to 1.11 per cent. Miscellaneous matter, mollusks, a biting bird louse (*Mallophaga*), and earwig remains figure as 2.15 per cent. Stinkbugs, which were secured four times, amount to 0.93 per cent.

The following insects were identified in these stomachs:

ORTHOPTERA.		COLEOPTERA—continued.	
<i>Plectrotettix</i> sp.-----	1	<i>Cerotoma denticornis</i> -----	1
<i>Homorocoryphus</i> sp.-----	1	<i>Coptocycla signifera</i> -----	1
<i>Scapteriscus didactylus</i> -----	5	<i>Diaprepes spengleri</i> -----	1
		<i>Lachnopus</i> sp.-----	1
HEMIPTERA.		HYMENOPTERA.	
<i>Thyanta</i> sp.-----	1	<i>Campsomeris dorsata</i> -----	1
COLEOPTERA.		<i>Strumigenys</i> sp.-----	1
<i>Selenophorus</i> sp.-----	1	<i>Pheidole fallax</i> var. <i>antillensis</i> -----	2
<i>Atanius stercorator</i> -----	1	<i>Odontomachus hæmatoda</i> subsp. <i>insularis</i> -----	2

Vegetable food.—The vegetable food of the mockingbird (68.79 per cent), though more than double the bulk of the animal food, has little economic significance. With the exception of less than 1 per cent of rubbish, it may roughly be called berries or fruits, all of wild species and none of importance to man.

¹ Bul. 30, Biological Survey, U. S. Dept. Agr., 1907, p. 53.

Berries of several species of rubiaceous shrubs were eaten freely, while the moral (*Cordia* sp.) and robe guayo (*Bourreria bourreria*) were the greatest favorites. Small wild figs (*Ficus* sp.), which grow commonly all through the country, were found in six stomachs, as were seeds of the nightshade family (*Solanum* sp.).

Seeds of plants in the following list were identified in the mockingbird stomachs examined:

Palmo (<i>Coccothrinax</i> sp.)-----	2	Nightshade (<i>Solanum</i> sp.)-----	6
Palmo real (<i>Roystonea borinquena</i>)--	2	Moral (<i>Cordia</i> sp.)-----	5
Wild fig (<i>Ficus</i> sp.)-----	6	Roble guayo (<i>Bourreria bourreria</i>)--	9
Amaranth (<i>Amaranthus</i> sp.)-----	1	Pendula (<i>Oitharexylum fruticosum</i>)--	1
Espino (<i>Xanthoxylum</i> sp.)-----	2	Tantillo (<i>Randia</i> sp.)-----	2
Bejuco prieto (<i>Paullinia pinnata</i>)----	1	Balsamo colorado (<i>Hamelia patens</i>)--	3
Jatropha (<i>Jatropha</i> sp.)-----	1	Palo moro (<i>Psychotria</i> sp.)-----	2
Adelia (<i>Adelia</i> sp.)-----	1		

Summary.—The mockingbird secures a little less than one-third of its aliment from the animal kingdom, the remainder being wild fruits and berries of no economic importance. In destroying noxious insects, as cutworms, weevils, and the notorious changa, it is a great aid to agricultural interests, and as such should be protected at all times.

PORTO RICAN THRUSH. *Mimocichla ardosiacea portoricensis* (Bryant).
ZORZAL, ZORZAL AZUL, ZORZAL DE PATAS COLORADAS.

The Porto Rican thrush is a tolerably common resident over the entire island, though less so on the dry south coast. It is a bird of dense, brushy areas, and in the hills it frequents coffee plantations, while a region of small streams, fringed with trees, running through brushy pastures, is also attractive. At times the birds run on the ground in the open, as robins do, but when flushed take refuge in thickets. When singing they mount to the top of a tree, perch in the thick leaves, and pay little or no attention to anyone moving about below. Their song, as with the pearly-eyed thrasher, is a series of disconnected notes, some of which are quite musical, and the whole effect is not unpleasing, though repetition makes it monotonous. Their note was a low *whew-a*, like that of a thrasher, and they were called up frequently by "squeaking" or by a whistled imitation.

The breeding season extends from February to June, varying somewhat in different parts of the island. Near Mameyes in February, birds were seen going through a sort of mating display, male and female running about on the ground with heads drawn in, the tail spread wide, and thrown forward over the back, so that the white tips were prominent. Young birds were common in June and July, and at that time the adults were molting badly. Taylor (1864, p. 166) has described the bill, eyelids, legs, and feet as a bright yellow in life, but this does not hold good in a considerable number of specimens examined in the flesh; these parts were near flame scarlet,¹ becoming more orange in June specimens, which were molting badly.

Near Ciales thrushes were in small bands eating fruit of the laurel (*Phæbe elongata*), and near Añasco one was seen eating the berries of the moral (*Cordia* sp.) and repeatedly driving out a gray kingbird which attempted to alight in the tree. They relish also the berries borne by the royal palm (*Roystonea borinquena*).

Food.—Thirty-two stomachs of this thrush were available for examination, all of the months from January to August with the exception of April being

¹ Ridgway, Color Standards and Color Nomenclature, 1912 (Jan. 16, 1913).

represented in the series. In these 36.54 per cent of the contents is animal matter and 63.46 per cent vegetable. Caterpillars, lizards, and beetles form a large share of the animal food, while the vegetable portion is composed of seeds and pulp of wild fruits and berries.

Animal food.—The mole cricket (*Scapteriscus didactylus*) was eaten by two birds, though it amounts to only 0.86 per cent of the total, and other orthopterous remains in three stomachs come to 0.36 per cent. Beetles (3.86 per cent) were captured by four birds. One bird had eaten a cane weevil root-borer (*Diaprepes spengleri*) and another contained small bits of a wireworm, the larval form of a click beetle. Fragments of cutworms were present in four stomachs and unidentified caterpillars in six more, which combined give a bulk of 12.25 per cent of the total. Ant remains (0.93 per cent), occurring in eight stomachs, are the only representatives of the great order of Hymenoptera found in the study of the food of this bird. Bug remains (Heteroptera) (2.64 per cent) occur in only two stomachs. In one of these was an odoriferous stink-bug (*Thyanta* sp.), a morsel pleasing to an avian palate only. Snails (2.62 per cent) were picked up by four birds and undoubtedly figure regularly in the food of this thrush, because of its terrestrial habits. Lizards and tree toads amount to 8.41 per cent and are the only beneficial animals destroyed. One of the lizards eaten was a siguana (*Ameiva exul*) and in seven stomachs were remains of the common lagarto (*Anolis* sp.). Two little tree toads (*Eleutherodactylus* sp.) were found. An earwig and two myriapods, included as miscellaneous items, come to 4.61 per cent.

Though only a trifle more than one-third of its food is composed of animal matter, this thrush is beneficial in its relation to agriculture. The only questionable portion of its food is that made up of insectivorous lizards and tree toads. When, however, the numbers of cutworms, beetles, ants, and bugs are arrayed against these the balance is decidedly in favor of the bird. Moreover, should any of the smaller vegetable-feeding snails be found injurious to crops this thrush would prove an ally against them.

The following were found in the stomachs of the Porto Rican thrush:

ORTHOPTERA.		HYMENOPTERA—continued.	
<i>Scapteriscus didactylus</i>	2	<i>Pheidole fallax</i> var. <i>antillensis</i>	2
		<i>Solenopsis globularia</i>	1
HEMIPTERA.		MOLLUSCA.	
<i>Thyanta</i> sp.	1	<i>Planorbis</i> sp.	1
		<i>Choanopoma</i> sp.	1
COLEOPTERA.		VERTEBRATA.	
<i>Diaprepes spengleri</i>	1	<i>Eleutherodactylus</i> sp.	2
		<i>Ameiva exul</i>	1
HYMENOPTERA.		<i>Anolis</i> sp.	7
<i>Camponotus</i> sp.	1		
<i>Pheidole</i> sp.	1		

Vegetable food.—Though the vegetable food of the Porto Rican thrush amounts to 63.46 per cent, none is of value to man. Berries of the camacey were taken and drupes of a nightshade (*Solanum* sp.) were swallowed entire. The small fruits of wild figs (*Ficus* spp.), growing as parasites or as true trees, were also relished, being found in five stomachs, and undoubtedly all the common wild fruits of the island are eaten in season.

The following seeds were identified:

Wild fig (<i>Ficus</i> sp.)	5	Camacey (<i>Miconia prasina</i>)	1
Tabonuco (<i>Dacryodes</i> sp.)	1	Nightshade (<i>Solanum</i> sp.)	3
Bejuco prieto (<i>Paullinia pinnata</i>)	2	Moral (<i>Cordia</i> sp.)	1
Camacey (<i>Miconia</i> sp.)	2	Balsamo colorado (<i>Hamelia patens</i>) ..	1

[WOOD THRUSH. *Hylocichla mustelina* (Gmelin).]**TORDO.**

Gundlach (1878, p. 170) saw a drawing of the wood thrush in the album of Bello, made from a specimen taken by Don Celedonio-Carbonell, of Cabo Rojo. Stahl (1883, p. 58) says that it is a very rare visitant, but noted no actual specimens. As this evidence does not appear sufficient to establish the wood thrush as a valid member of the Porto Rican avifauna it is included as hypothetical.]

PORTO RICAN CROW. *Corvus leucognaphalus leucognaphalus* Daudin.**CUERVO. /**

Formerly reported abundant over much of the island, the Porto Rican crow is now almost extinct. A few are said to occur below San Sebastian, and in the more inaccessible portions of El Yunque they are still fairly common. Occasionally small flocks come down from the mountains to the coast near Mameyes. There were formerly a few near Utuado, but Mr. L. B. Strube, of the Hacienda Jobo, says that none have been seen there for five or six years, though there is no apparent reason for their disappearance, as on his plantation at least they were not disturbed. In the region between Lares and Las Marias it was said that there was formerly a smaller species that had not been seen for many years, and it is possible that there were once two species on the island, as on Santo Domingo and Cuba to-day.

These birds have more the nature, habits, and call notes of ravens than crows. They seem to thrive only where there are extensive growths of natural forest, and when these are cut down the crow disappears. In March along the west fork of the Rio Mameyes they were breeding, the nests apparently containing both eggs and well-grown young. All were inaccessible, however, being located in the tops of the tall tabanuco trees. The adults kept well concealed in the leaves high above, and only by patient watching could they be located. They exhibited considerable curiosity, however, and once, when I was hidden in some tall grass, two flew down to examine the place. On a second visit to this colony all the birds left, going higher into the mountains, though every half hour or so four or five would come circling back, high in the air, and perhaps one or two would alight on a dead limb projecting above the forest, where they croaked and called, lifting the wings nervously. Later a flock of about 25 were found near the forks of the Rio Mameyes, but these were very wild, keeping entirely to the higher slopes. On days when it was cold and rainy on the summit of El Yunque they descended into the warmer valleys, as the parrots did, and when it cleared circled back to the higher peaks.

The ordinary call note is a high *klook*, or a deep *wal-lough*, varied by any number of indescribable gutturals and gabbling calls, with none of the vociferous cawing of our crows. The natives claim that the birds live for many years, and credit them with great sagacity, asserting that birds captured while young may be taught to speak a few words of Spanish. They are prized as food by the country people and were formerly hunted as game.

Food.—In nine stomachs collected around El Yunque in March animal food amounts to only 10.56 per cent, and is composed of fragments of a nestling passerine bird in one stomach and bones of tree toads (*Eleutherodactylus* sp.) in two others. The vegetable food (89.44 per cent), by far the larger part, is made up of wild berries and drupes of a number of species, several of which were unknown. The drupes of the tabonuco (*Dacryodes excelsa*) were found in three stomachs and a palm berry (*Acrista monticola*) in another, while seeds of rubiaceous plants were common. In the field the birds were observed feeding on the guaraguou (*Guarea trichiloides*), tabonuco, and jagua (*Genipa* sp.), and other fruits are added to its dietary as the seasons change. None of these are of economic importance, but the animals destroyed are all friends of man,

so that the crow is an injurious species. Its numbers, however, are now so few and it is so closely confined to its restricted range that it has little or no influence on the balance of nature. Hence no destructive measures are necessary, and it should be conserved as an interesting species. Unlike the crow of the United States, it can not accommodate its habits to changed conditions and can be expected to survive only in the Government forest reserve on El Yunque de Luquillo.

LATIMER'S VIREO. *Vireo latimeri* Baird.

JULIAN CHIVI.

Latimer's vireo is a tolerably common resident species in Porto Rico, found in many localities, though having a local range. None were observed east of Trujillo Alto, Caguas, and Patillas, and in the western part of the island they were found only under certain conditions. The birds frequented coffee plantations somewhat, but were most common in the limestone hills, covered with dense brush and matted with creepers, a prominent feature of the landscape along the north coast. In the dry hills of the south coast also they were common and were perhaps most abundant in the forest growth along the Rio de la Lapa, back of Salinas. They worked industriously through the brush and tangles, sometimes high up in the trees, but more often near the ground. They exhibited some curiosity, and once one came out and scolded with a wrenlike chatter for several minutes, until the brush was full of peering grassquits, honey creepers, and spindalis. The females seem to be almost silent, but the males sing incessantly a sharply accented song, in imitation of which it gets its native name of *julian chi-vi*. There are two distinct strains in this song, and the bird sometimes changes from one to the other, repeating them 22 or 23 times a minute, frequently keeping this up for an hour. A quick scolding note like *chee chee chur chur chur* is sometimes heard.

The birds nested in April and May, and young birds were seen July 5 still following their parents with soft call notes. Bowdish (1902-3, p. 16) records immature birds taken as late as October. In May the males sang incessantly, frequently remaining on one perch for half an hour or so, but by the middle of June they were mostly silent.

Food.—Forty-three stomachs of this bird were collected, representing the food of every month from December to August, inclusive, except March, and it was found that 86.21 per cent of the contents by bulk was formed by animal matter and 13.79 per cent by vegetable. Orthoptera, Homoptera, and Lepidoptera are the largest items in the class of insects, while the vegetable matter is composed of seeds.

Animal food.—Even Latimer's vireo relishes nymphs of the mole cricket (*Scapteriscus didactylus*), which were found in 6 stomachs, though they amount to but 0.9 per cent. Grasshopper remains were found in 6 stomachs, and indeterminate Orthoptera in 10. One bird had secured a roach and another a mantis. All of these make up 21.77 per cent, a surprising amount for a bird of this family. The insects taken were almost entirely nymphs, though some larger adults were secured. Undoubtedly nearly all the unidentified material belonged to the family Locustidæ, as the members of this group are found largely in foliage. Of the true bugs, homopterous remains come to 15.1 per cent, much of which is formed by cicadas (*Proarno hilaris*), large morsels for a bird of this size. Many lantern flies and leaf hoppers also were secured, the first named being found frequently. Two assassin bugs and three stinkbugs come to 3.67 per cent. Leaf beetles (Chrysomelidæ) were found in 6 stomachs and amount to 2.76 per cent, while longicorn beetles make up 1.75 per cent. Snout beetles were found in 21 stomachs and, though amounting to only 3.26 per cent, are an

important item, as they are all species of small size. The rice weevil (*Calandra oryzeæ*), a species well known as a pest in stored grains, flour, and other food-stuffs, was identified three times. Miscellaneous beetles—click beetles, fireflies, buprestids, and others—amount to 3.56 per cent.

Caterpillars, all small, were found in 14 stomachs, and the remains of moths, frequently a mere trace of scales, in 7; these total 21.88 per cent, one of the most important divisions in the food. The remains of Diptera amount to 1.25 per cent, and Hymenoptera to only 0.92 per cent. The latter are mainly beneficial, in one stomach being found a parasite of ants (*Kapala* sp.), and in another a small bee. Spiders (6.29 per cent) occur in 12 stomachs. Three birds had eaten earwigs, and one had captured a tiny lizard. Miscellaneous matter makes up 3.1 per cent.

Latimer's vireo is entirely beneficial, the only valuable insects consumed being a few parasitic Hymenoptera and predacious ladybird beetles. In addition to these, the spiders may be considered of value; but arrayed against this meager showing are hosts of destructive beetles, bugs, and caterpillars. At present the birds frequent the coffee plantations, and, as they are common in places about the borders of citrus groves in brushy areas, they may in time extend their foraging into the groves themselves. It is rather surprising to find a small bird feeding upon the mole cricket, but this is understood when it is seen how largely other Orthoptera enter into its diet.

The following insects were identified in these stomachs:

ORTHOPTERA.		COLEOPTERA—continued.	
<i>Periplaneta</i> sp.....	1	<i>Acmæoderia</i> sp.....	2
<i>Scapteriscus didactylus</i>	6	<i>Photinus</i> sp.....	1
		<i>Eburia</i> sp.....	2
HEMIPTERA.		<i>Leptostylus</i> sp.....	4
<i>Ormenis</i> sp.....	1	<i>Cryptocephalus</i> sp.....	5
<i>Proarno hilaris</i>	6	<i>Myochrous</i> sp.....	1
<i>Thyanta</i> sp.....	1	<i>Helops</i> sp.....	2
		<i>Strongylium</i> sp.....	1
COLEOPTERA.		<i>Euscepes porcellus</i>	3
<i>Scymnus roseicollis</i>	1	<i>Calandra oryzeæ</i>	3
<i>Monocrepidius bifoveatus</i>	1		
		HYMENOPTERA.	
		<i>Kapala</i> sp.....	1

Vegetable food.—Though vegetable items come to 13.79 per cent in these stomachs, none are of commercial value, all being small wild berries. This is much more vegetable food than has been found in representatives of this family in the United States, and, as it occurs in 23, or more than half of the total number of stomachs examined, it may be considered a regular constituent of the food. The berries of the camacey (*Miconia prasina*) and espino seem to be the most favored. Every stomach taken in December contained large numbers of these seeds; for this month they form exactly one-third of the bulk, but in the following months they are more scattering. No sand or gravel was found, so that berries must have been eaten solely for the pulp, though some of the softer seeds may have been digested. The following seeds were found:

<i>Paspalum</i> (<i>Paspalum</i> sp.).....	1	Camacey (<i>Miconia prasina</i>).....	11
<i>Vinagrillo</i> (<i>Ovalis</i> sp.).....	1	<i>Adelia</i> (<i>Adelia</i> sp.).....	1
<i>Espino</i> (<i>Xanthoxylum</i> sp.).....	8	<i>Aji</i> (<i>Capsicum</i> sp.).....	1

[RED-EYED VIREO. *Vireosylva olivacea* (Linnaeus).
BIEN-TE-VEO.]

Gundlach (1878, p. 169) saw the red-eyed vireo figured in the album of Bello, who drew it from a specimen in the collection of Don Celedonio-Carbonell. This record is not considered sufficient to include the bird as a Porto Rican species, except as hypothetical. It might be easily confused with a worn or poorly marked specimen of the Jamaican vireo.]

JAMAICAN VIREO. *Vireosylva calidris calidris* (Linnaeus).

BIEN-TE-VEO.

The Jamaican vireo is a common summer visitant to this region. The first one was seen near Mameyes February 14, and from that date on they were common. Ranging over the entire island of Porto Rico, they were found everywhere in coffee plantations, brushy pastures and ravines, and in shade trees about houses. Bowdish (1902-3, p. 16) remarks that apparently they are partially migratory, while Gundlach (1878, p. 168) says that they occur from February 14 to the end of August. In the National Museum is a specimen taken February 13, 1899, at Hucare, by A. B. Baker, of the Fish Commission, while Stahl (1887, p. 451) notes one February 5, 1887, the earliest date known for the species. Males seemed to arrive first and came in full song, while no female was actually taken until April 11, after which they, too, were common. On March 9 there was a migratory wave of these vireos, as in the morning at the Hacienda Catalina the coffee plantations were full of their songs but next day they were gone. In fall these birds had completed the molt by the first week in August, and on the 16th of that month their numbers suddenly decreased, after which they were evidently migrating, the last one being observed on August 31 at Cabo Rojo.

Slow and leisurely in habit, they work through the leaves and twigs, sometimes singing for several minutes from one perch and exhibiting no fear. The song is a series of couplets, closely resembling that of the red-eyed species, and they have the usual scolding note of the vireos. The breeding season began the first of May and lasted through June. No nests were found, but at Lares June 29 a boy brought in a nestling and described the nest as being in a banana plant. A juvenal female in the National Museum was taken at Mayagüez May 30, 1901, by Bowdish. Throughout July young birds were common, either shifting for themselves or following their parents with a soft insistent *chit chit*, while the adults answered with another low plaintive note, different from the usual call. Two seemed to be the usual number in a brood. During the breeding season the birds have a circumscribed range. Often a male was found in a small isolated grove and remained there throughout the day. In August only a few were heard singing. The iris of this species is bright reddish brown.

Eighty-four stomachs of the Jamaican vireo were examined, distributed evenly through the months from February to August, and animal food was found to comprise 42.18 per cent and vegetable 57.82 per cent.

Animal food.—Remains of grasshoppers (Locustidæ) were found in three stomachs, elongated walking sticks (Phasmidæ) in two, miscellaneous Orthoptera in nine, and mantids in three. These in combination come to 6.34 per cent. Cicadas (*Proarna hiliaris*) were eaten by six birds, a lantern fly (*Ormenis* sp.) by one, and other small Homoptera by three, all amounting to 6.37 per cent. Among other bugs one stinkbug (*Nezara* sp.) was identified and one squash bug (*Spartocera fusca*), both members of families whose species are injurious. These with bits of an ambush bug come to 1.92 per cent.

Leaf beetles comprise 1.51 per cent of the total bulk and the cane weevil root-borer (*Diaprepes spengleri*), found in three instances, 0.51 per cent. Other snout beetles, which in three instances were coffee leaf-weevils, amount to 3.35 per cent. Weevils as a class occurred in 32 stomachs, so that they are an important item in the food. Ladybird beetles were eaten five times, but only made 0.42 per cent. A few darkling, longicorn, and dung beetles amount to 0.64 per cent. Twenty-one birds had eaten caterpillars, which as vegetable feeders must be reckoned as injurious. They form the largest item of the animal food (9.7 per cent). Hymenoptera, at least half of which may be called

beneficial, amount to 2.03 per cent. A wasp and an ant were identified among these. Diptera amount to only 0.21 per cent and were eaten by a single bird in February. Earwigs (0.83 per cent) were taken six times. Spiders (7.74 per cent), eaten by 30 birds, were taken in largest numbers in March and April. Little tree toads (*Eleutherodactylus* sp.) were captured twice, and with a very small quantity of miscellaneous matter make up 0.61 per cent.

The only harm done by this vireo is in the destruction of a few ladybirds, beneficial Hymenoptera, and tree toads. But to offset these are found much larger numbers of injurious beetles, bugs, caterpillars, and other insects, in destroying which great good is accomplished. The bird is especially useful in coffee plantations and it abounds there. It comes, too, about the villages and country houses, where it aids in ridding the shade trees of their pests.

The following were definitely identified in the stomachs:

HEMIPTERA.		COLEOPTERA—continued.	
<i>Ormenis</i> sp.-----	1	<i>Cryptocephalus</i> sp.-----	9
<i>Proarno hilaris</i> -----	6	<i>Myochrous</i> sp.-----	1
<i>Phymata</i> sp.-----	1	<i>Helops</i> sp.-----	2
<i>Spartocera fusca</i> -----	1	<i>Lachnopus</i> sp.-----	3
<i>Nezara</i> sp.-----	1	<i>Diaprepes spengleri</i> -----	3
COLEOPTERA.		HYMENOPTERA.	
<i>Scymnillus</i> sp.-----	3	<i>Cerceris</i> sp.-----	1
<i>Cycloneda limbifer</i> -----	3		
<i>Atanius stercorator</i> -----	1	VERTEBRATA.	
<i>Eburia</i> sp.-----	1		
<i>Leptostylus</i> sp.-----	1	<i>Eleutherodactylus</i> sp.-----	2

Vegetable food.—Vegetable matter (57.82 per cent) was found in 80 of the 84 stomachs available for laboratory examination. It was composed almost entirely of wild fruits and berries, though frequently its presence was detected only by the seeds, the pulpy exterior having been completely digested. In some cases also only the skins of small fruits were found, so that possibly the pits are sometimes removed before swallowing. None of the fruits taken have any importance to man nor would their dissemination through seeds scattered by the birds be of any consequence. Those sought most eagerly may be determined from the list which follows:

Wild fig (<i>Ficus</i> sp.)-----	2	Nightshade (<i>Solanum</i> sp.)-----	3
Espino (<i>Xanthoxylum</i> sp.)-----	9	Aji (<i>Capsicum</i> sp.)-----	8
Guaraguou (<i>Guarea trichilioides</i>)-----	11	Moral (<i>Cordia</i> sp.)-----	6
Jatropha (<i>Jatropha</i> sp.)-----	2	Roble guayo (<i>Bourreria</i> sp.)-----	1
Camacey (<i>Miconia</i> sp.)-----	2	Tantillo (<i>Randia aculeata</i>)-----	1
Camacey (<i>Miconia prasina</i>)-----	1	Palo moro (<i>Psychotria brachiata</i>)-----	1
Adelia (<i>Adelia</i> sp.)-----	15	Concombre (<i>Cucumis</i> sp.)-----	1

AMERICAN REDSTART. *Setophaga ruticilla* (Linnæus).
REINITA, CANDELITA, COLI RUBIO.

The American redstart is a common winter visitant to Porto Rico. The last one for the spring I saw on Culebra Island April 19, and Dr. Richmond (MS.) noted one at Ponce April 16, 1900. Stahl (1887, p. 451), says that they arrive from the north in August. These birds frequent the mangroves, forest growths, and coffee plantations, and sometimes shade trees about houses. The greater portion seen were immature birds and females, though occasionally males in full plumage were observed. As always, these birds were very active, searching through the limbs for insects, and expertly catching insects on the wing. On El Yunque, in the dense forests, they were seen up to 1,500 feet altitude, and else-

where in more open localities were found at the highest elevations. Next to the parula warbler this is the most common of the wintering warblers.

Food.—Thirteen stomachs of the redstart were examined, taken in December, January, February, and April, and in these animal food amounts to 100 per cent. Small lantern flies (*Fulgoridæ*) occur nine times and form 37.23 per cent of the total. Longicorn beetles make up 0.57 per cent, snout beetles 1.5 per cent, and miscellaneous species 2.54 per cent. All are classed as injurious species save a single ladybird beetle, so small that it is lost in the bulk of others. Moth remains amount to 11.75 per cent, while no caterpillars were eaten. Hymenopteran remains (6.67 per cent) were found in five stomachs. Approximately two-thirds of these are small species, probably of parasitic habit. One that parasitizes ants was definitely identified as a species of *Kapala*. Diptera (39.24 per cent) were present in eight of the stomachs examined. One bird had eaten a spider, and another insect eggs, both amounting to only 0.5 per cent.

Though present only in winter, this small warbler is a bird of economic importance. It destroys thousands of lantern flies, abundant in the trees and shrubbery, as well as many beetles, moths, and flies. A very small percentage of its food is taken from beneficial species of insects, the remainder being entirely injurious. This bird is entirely insectivorous and does not feed upon any of the abundant wild berries, a fact that increases its importance, as it destroys proportionately more insects than do the more or less vegetarian resident species of similar habit.

The following insects were identified in these stomachs:

HEMIPTERA.		DIPTERA.	
<i>Ormenis</i> sp-----	4	<i>Compsomyia macellaria</i> -----	1
		<i>Eristalis albiceps</i> -----	1
		<i>Sarcophaga</i> sp-----	1
COLEOPTERA.		HYMENOPTERA.	
<i>Scymnus roseicollis</i> -----	1		
<i>Leptostylus</i> sp-----	1		
<i>Cryptocephalus</i> sp-----	1		
<i>Mordellistena</i> sp-----	1	<i>Kapala</i> sp-----	1
<i>Euscepes porcellus</i> -----	1		
<i>Platypus</i> sp-----	1		

NORTHERN YELLOW-THROAT. *Geothlypis trichas brachidactyla* (Swainson).
PICA TIERRA.

The northern yellow-throat is of uncertain status for Porto Rico. Hartlaub (1847, p. 611) includes it in his list, and Gundlach quotes this record. Stahl (1883, p. 59) says that it is a rare migrant, and Gundlach (1878, p. 187) remarks that it is a rare winter visitant, but does not say that he secured it. Cory (1892, p. 119) lists it for Porto Rico without comment.

WATER-THRUSH. *Seiurus noveboracensis noveboracensis* (Gmelin).
PIZPITA DE MANGLE, PIZPITA CHICA.

The water-thrush is a fairly common winter visitant in the coastal region of Porto Rico, being noted at Mameyes February 9 to 29 and Cabo Rojo August 30. Dr. Richmond (MS.) saw one at Arecibo April 1, 1900, and Bowdish collected one on Mona Island August 18, 1901, where he found them fairly common. I saw them on Culebra Island from April 6 to 19, and one was noted on Luis Peña Island (Southwest Cay) April 11. In life this water-thrush can not be distinguished from the next subspecies described, Grinnell's water-thrush (*Seiurus noveboracensis notabilis*), and part of the above records refer to the latter. Specimens of this form were collected only on Culebra Island April 6 and 12.

There is no reason to suppose, however, that it was not at least as common as *S. n. notabilis* in the other localities noted.

These water-thrushes occur only in the mangroves of the coastal region, where they are found about bays and lagoons feeding on the ground, and though their sharp call notes are heard repeatedly, the birds themselves are usually hidden. While I was watching for clapper rails they frequently came walking along through the mud and over the roots, teetering the tail incessantly. In April they were singing as clearly as in the North.

Food.—Two specimens of this subspecies and two of *S. n. notabilis* were collected and their food is considered together. Of these four stomachs one was taken at Mameyes in February and the other three on Culebra Island in April. Fly pupæ and a few adults were present in three stomachs and amount to 43 per cent of the total. Ants (24 per cent), of which one bird had eaten 40, were found in three stomachs. Water scavenger beetles were found in two instances and a hister beetle (*Hister* sp.) once. In one stomach were five water boatmen (*Plea* sp.) and another aquatic bug, and two contained the remains of small crabs (in one case of *Uca*). In single stomachs were found the jaw of an orthopteran, a lantern fly, and a bone from the head of a tiny fish.

In destroying ants and fly larvæ these birds are beneficial, and though few in number they aid in restraining these insects. Only part of the beetles taken may be considered beneficial, and these are relatively small in bulk. In working over the muddy floors of the great mangrove swamps they perform a service peculiar to themselves and one or two species of similar habits, and are of undoubted value.

GRINNELL'S WATER-THRUSH. *Seiurus noveboracensis notabilis* (Ridgway).
PIZPITA DE MANGLE, PIZPITA CHICA.

One Grinnell's water-thrush was collected at Mameyes February 14 and another on Culebra Island April 12. This is the first record from Porto Rico. In habits and actions it is similar to the typical subspecies, in the discussion of which will be found brief notes on its food. Both of these water-thrushes are beneficial.

LOUISIANA WATER-THRUSH. *Seiurus motacilla* (Vieillot).
PIZPITA CHICA.

The Louisiana water-thrush is a fairly common winter visitant to Porto Rico. The birds may arrive in September, though there are no positive records, and the first that I saw were at Cayey January 17. They were common in the mangrove swamps along the coast and inland followed the rapid streams, frequenting the parts bordered by brushy growth or running through coffee and banana plantations. The call note is noticeably higher than that of the other water-thrush, from which it can readily be distinguished.

Food.—In five stomachs collected at Cayey and Aibonito in January animal food forms 98 per cent, vegetable 2 per cent. Remains of flies (33 per cent) were present in three stomachs. Water beetles (Parnidæ and others) were found in three stomachs and leaf beetles in two. In one bird was a tree hopper and in two others were indeterminate bug remains. A dragon fly was found once and spider remains and bits of a scorpion twice. Three-fourths of the contents of one stomach was composed of fragments of a snail, and in another was found a tree toad (*Eleutherodactylus* sp.). Two birds had eaten seeds, in one case those of the ají (*Capsicum* sp.). In these birds the number of harmful insects consumed is slightly in excess of the beneficial species destroyed (including also spiders and the tree toad).

OVEN-BIRD. *Seiurus aurocapillus* (Linnaeus).

PIZPITA DORADA.

The oven-bird is a tolerably common winter visitant to Porto Rico and Vieques Island. Bowdish (1902-3, p. 19) notes one October 14, 1901, as his first fall record, and Gundlach (1878, p. 175) says that they arrive in October. Birds were seen in the forests of El Yunque up to 900 feet elevation, and in the central part of the island they were observed at Aibonito (1,900 feet altitude). They frequent thickets and second-growth forests many times in dry localities. Here they feed on the ground, flying up to low perches when alarmed. They were entirely silent. In the coastal regions they are frequently seen in cane fields.

Food.—In 13 stomachs of this bird available for laboratory examination animal food amounts to 62.43 per cent and vegetable to 37.57 per cent. These birds were collected in the months from December to April, inclusive. In all these stomachs were considerable quantities of gravel, and all animal matter was ground very fine. Weevil remains (4.8 per cent) were present in four stomachs taken in April. Other beetle remains (9.63 per cent) in eight stomachs were so finely broken that they could not be determined. Ants were eaten by eight birds and form the large amount of 8.5 per cent. Other Hymenoptera make up only 0.4 per cent. Orthopterous remains (2.17 per cent) include a walking stick, a grasshopper, and others. A caterpillar (0.5 per cent) was found in one stomach and spiders (2.33 per cent) in three. Snails, in most instances broken up in very small pieces, were eaten by eight birds and amount to 30.17 per cent. A single tree toad comprises 0.93 per cent and miscellaneous animal matter 3 per cent.

The oven-bird is wholly beneficial in its food habits and is remarkable for the large number of ants eaten, as well as many weevils and other beetles. Snails are much relished, and form nearly half the animal food. A list of identified specimens in different classes follows:

COLEOPTERA.		MOLLUSCA.	
<i>Euscepes porcellus</i> -----	1	<i>Planorbis</i> sp-----	1
		<i>Subulina</i> sp-----	2
HYMENOPTERA.		VERTEBRATA.	
<i>Wasmannia auropunctata</i> -----	1		
<i>Cyphomyrmex rimosus</i> -----	1	<i>Eleutherodactylus</i> sp-----	1

Vegetable food.—Of the vegetable matter contained in these stomachs 36.9 per cent was composed of seeds and 0.67 per cent may be classed as rubbish. The oven-bird has a strong, muscular gizzard and takes large quantities of sand, so that the seeds are broken and ground until they are fit for digestion. None are of economic value, as may be judged from the list which follows:

<i>Ichnanthus</i> (<i>Ichnanthus pallens</i>)----	4	Camacey (<i>Miconia prasina</i>)-----	3
<i>Paspalum</i> (<i>Paspalum</i> sp.)-----	2	Concombre (<i>Cucumis</i> sp.)-----	2
Stargrass (<i>Hypoxis</i> sp.)-----	3		

PALM WARBLER. *Dendroica palmarum palmarum* (Gmelin).

REINITA, BIJIRITA DE PALMAS, BIJIRITA PALMERA.

A single specimen of the palm warbler, a rare winter visitant to Porto Rico, was taken in a mangrove swamp bordering the Rio Mameyes, north of Mameyes, on February 16, 1912. In the United States National Museum is a specimen taken January 8, 1899, at Caguas by A. B. Baker, and another from Arecibo, April 4, 1900, by Dr. C. W. Richmond. Bowdish (1902-3, p. 18) records them from San Juan February 12, March 10, and April 8, 1900. The stomach of the single bird collected at Mameyes was empty.

PRAIRIE WARBLER. *Dendroica discolor* (Vieillot).

REINITA, BIJIRITA GALANA.

The prairie warbler is apparently much more common as a migrant than as a true winter visitant. Bowdish (1902-3, p. 19) records it on September 23, 1900, and the last birds seen in the present investigations were noted on April 10, on Culebra Island. In Porto Rico these birds occur at the highest altitudes (above Aibonito, at 2,000 feet), and are found in brushy growths, in pastures where there are thickets, and along the hedges of emajagua (*Paritium tiliaceum*). Dry, brushy growths back of the beaches also are favorite places, and many live in the dry forests of Vieques. In spring there was a marked diurnal movement toward the west, and on Vieques there were distinct waves of migration on March 19 and March 27. Another was noted on Culebra Island on April 9. In each case the birds were in company with many other warblers.

Food.—For the study of the food of the prairie warbler 15 stomachs, taken in December, January, March, and April, were available. Animal food forms the entire content. The largest single item in these stomachs is composed of Fulgoridæ, which comprise 42.78 per cent of the food and were found in nine stomachs. Other bug remains, mainly fragments of an ambush bug (*Phymata* sp.), make up 1 per cent. Three birds had eaten leaf beetles (2.9 per cent) and one a weevil (0.2 per cent). Other beetle remains, among which a longicorn, a skin beetle, and a click beetle were identified, make up 12.9 per cent. Caterpillars found by five birds and moths by two make 12.7 per cent, while fly remains in two amount to 0.35 per cent. Ants in four stomachs form 3.72 per cent of the total, while other Hymenoptera, captured by a single bird, come to only 0.1 per cent. The only questionable part of the food of this bird is found in the large number of spiders eaten (19.59 per cent). These are found in eight, or more than half, of the stomachs examined. Miscellaneous animal matter totals 3.76 per cent.

Among beneficial species the prairie warbler ranks high, as practically four-fifths of its food is composed of harmful insects. Its destruction of spiders is a questionable benefit, but it consumes such large numbers of lantern flies (Fulgoridæ) that there can be no doubt as to its usefulness. In common with other birds of the same family, the wood warblers, it feeds to a considerable extent on ants while in Porto Rico, insects that in the Tropics are very destructive.

The following were identified in these stomachs:

HEMIPTERA.		ARACHNIDA.	
<i>Ormenis</i> sp-----	2	<i>Wala vernalis</i> -----	1
<i>Phymata</i> sp-----	1	<i>Theridula triangularis</i> -----	1
		<i>Tibellus</i> sp-----	1
COLEOPTERA.			
<i>Cryptocephalus</i> sp-----	3		

BLACK-POLL WARBLER. *Dendroica striata* (J. R. Forster).

REINITA, BIJIRITA ESTRIADA, BIJIRITA RAYADA.

Gundlach (1878, p. 181) observed the black-poll warbler, a rare migrant in Porto Rico, in October at Aguadilla, and records one as seen at Bayamon. Stahl (1883, p. 139) had a male taken in Porto Rico in his collection, and (1887, p. 451) says that the birds arrive the middle of August.

ADELAIDE'S WARBLER. *Dendroica adelaidæ* Baird.

REINITA, BIJIRITA ADELAIDA, BIJIRITA MARIPOSERA.

A fairly common resident species in Porto Rico, Adelaide's warbler occurs in most parts of the island, but is local in distribution. The only ones seen at

a high altitude were in the limestone hills west of Cayey, at about 1,200 feet elevation, the birds being found elsewhere mainly below 500 feet. They are fairly common on Vieques also, and this is the first time they have been recorded from that island.

On the south side of Porto Rico they are found in dry forest growth covering the hills, and on the north coast in second-growth forest tangled with vines and creepers, and where these conditions are wanting the birds are not found. Quick and active in habits, they feed rapidly through the tips of the twigs, tumbling down through the limbs after a moth or flying out to capture an escaping insect on the wing. They are partial to dense tangles of vines, and, though not wild, it was sometimes hard to find them for this reason. The song of the male is a sudden trilling outburst, somewhat like that of the pine warbler (*Dendroica v. vigorsi*), and always there follow protesting notes from a female near by. The males sing at short intervals during the forenoon and evening and occasionally during the heat of the day. Many were seen along the Rio de la Lapa, back of Salinas, where they were exceptionally abundant.

The birds appear to nest in May and June, and young were first observed near Quebradillas July 3, but after that date they were common. Near Yauco, on May 22, a nest was found in a thicket, not quite completed. It was saddled in a forked limb of a bush, about 4 feet from the ground. Externally its construction was of gray moss, shading in perfectly with its surroundings, while the lining was of fine grass. Bowditch (1902-3, p. 18) secured a juvenal male near Aguadilla June 15. The birds were molting badly in August.

Food.—For detailed analysis 41 stomachs of this bird were available, taken in every month from December to August except June. These contained nothing but animal matter. Six birds had secured Orthoptera, 2.61 per cent of the total. Three of these had eaten grasshoppers (Locustidæ). Insects that were actually identified as lantern flies amount to 46.82 per cent, and were found in 24 of the stomachs, while remains definitely determined only as those of small homopterous insects come to 12.73 per cent more. Thus these insects, destructive to many cultivated plants, form a little more than two-thirds of the entire food. Other bugs, assassin bugs in two instances, form 1.84 per cent. One bird had taken 12 stinkbug eggs.

Beetles are well represented and, with the exception of ladybird beetles in three instances (0.05 per cent), are all harmful species. Skin beetles come to 0.28 per cent and longicorns to 5.81 per cent. Leaf beetles (1.92 per cent) were eaten by 11 birds. Among the weevils, curculios, found in seven instances, come to 3.33 per cent and other snout beetles amount to 2.53 per cent. A few miscellaneous Coleoptera remains figure as 0.36 per cent. Caterpillars were eaten 6 times and moths 11, all amounting to 11.23 per cent. Hymenoptera comprise 2.12 per cent of the food, and are mostly small parasitic species, though ants were eaten three times. Spiders (7.29 per cent) were eaten 14 times. Diptera comprise only 0.45 per cent, and miscellaneous animal matter 0.63 per cent. One tree toad (*Eleutherodactylus* sp.) was eaten.

Adelaide's warbler is one of the few endemic birds that draw their entire sustenance from the animal kingdom. Enormous numbers of small Homoptera are destroyed by these birds; in fact, from this group of insects alone is gathered more than two-thirds of the bird's entire aliment. Besides these, many harmful weevils and other beetles, caterpillars, moths, and other insects are destroyed. In capturing small numbers of ladybird beetles, parasitic Hymenoptera, and spiders, some damage is done, but this is compensated for many times over by the great numbers of injurious insects which form the bulk of the food.

The following were identified in the stomachs:

HEMIPTERA.		COLEOPTERA—continued.	
<i>Ormenis</i> sp-----	5	<i>Euscepes porcellus</i> -----	.1
		<i>Apion</i> sp-----	2
COLEOPTERA.		HYMENOPTERA.	
<i>Scymnillus</i> sp-----	1		
<i>Cryptorhopalum</i> sp-----	3	<i>Kapala</i> sp-----	1
<i>Eburia</i> sp-----	1		
<i>Leptostylus</i> sp-----	3	AMPHIBIA.	
<i>Cryptocephalus</i> sp-----	8		
<i>Metachroma</i> sp-----	2	<i>Eleutherodactylus</i> sp-----	1

SYCAMORE WARBLER. *Dendroica dominica dominica* (Linnæus).

REINITA, BIJIRITA DOMINICA.

Sundevall (1869, p. 596) notes one specimen of the sycamore warbler received from Hjalmarsen, while Gundlach (1878, p. 184) found it a common winter visitant from September to March. I did not meet with it.

MYRTLE WARBLER. *Dendroica coronata* (Linnæus).

REINITA, BIJIRITA CORONADA.

The myrtle warbler is a tolerably common winter visitant. The first was seen January 5 in the plaza at Caguas, and from then on it was noted occasionally in the forests and more open growth. In February, about Mameyes, there seemed to be some migratory movement among these birds. The last one was seen in the town of Isabel II, on Vieques Island, April 1.

Only four stomachs of this bird were secured in Porto Rico, so that the food can be merely indicated. Caterpillars completely fill one stomach and form one-fourth of the contents of another. The remains of small Homoptera are prominent in two stomachs. One bird had eaten a large number of Diptera, and small particles of beetles occur twice. Spider remains form three-fourths of the contents of one stomach and are found in small quantities in another. This is the only element in the food that counts against the bird, the majority of the insects taken being harmful species. From the meager data available this warbler while in Porto Rico seems to conform in food habits with the prairie warbler and others of the same genus.

BLACK-THROATED BLUE WARBLER. *Dendroica cærulescens cærulescens* (Gmelin).

REINITA, BIJIRITA APLOMADA.

Gundlach (1878, p. 179) records the black-throated blue warbler for the island on the strength of a drawing seen in the album of Bello and on a record by Don Tomas Blanco. Stahl (1883, p. 139) had a specimen in his collection from Porto Rico. I found it a rare winter visitant, noting the first at Río Piedras December 22 and the last on Vieques Island March 27, when several were observed with other migratory warblers. On El Yunque, in March, they were fairly common in the dense forests. They scold vigorously at intruders, and their demonstrations attract all the other birds in the forest. Near Río Piedras they were eating berries of the sapalo (*Palicourea riparia*).

Eight stomachs of this bird were collected and in these animal matter forms 75.5 per cent and vegetable 24.5 per cent of the contents. The vegetable food was found in the three stomachs taken in December and January and consisted of seeds of the camacey (*Miconia prasina*). Of the animal food 19.46 per cent is composed of lantern flies (*Fulgoridæ*), which seem to be favorites with all warblers. Remains of other bugs come to 6.87 per cent, while weevils of various sorts make the large sum of 14.25 per cent. Among them were found a coffee

leaf-weevil (*Lachnopus* sp.), a shot-hole stalk-borer (*Xyleborus* sp.), and a curculio (*Eusecpes porcellus*). Engraver beetles (*Platypus* sp.) were found in three stomachs. Longicorn beetles (2.17 per cent) were eaten three times. Miscellaneous beetle remains figure as 2.38 per cent. Though fragments of flies were found in two stomachs only, they comprise 10.09 per cent of the total. Moth remains were identified once and caterpillars twice, and together they amount to 6.7 per cent. In one stomach was an ant and in another small bits of a hymenopteran, which come to 0.96 per cent. Spiders were eaten three times and make up 12.62 per cent of the food.

The black-throated blue warbler shares with others of its family a marked taste for lantern flies and other small Homoptera, all harmful insects. One-eighth of the food, as shown in these few stomachs, is composed of spiders, but a larger portion is made up of injurious weevils, caterpillars, beetles, and flies. Thus, though a migrant species, this warbler has considerable economic importance. Because of its retiring habits it is little known, but may be discovered by those interested in birds who search for it.

CAPE MAY WARBLER. *Dendroica tigrina* (Gmelin).
REINITA, BIJIRITA DE COSTA.

The Cape May warbler is recorded as a winter visitant from fall until May by Gundlach (1878, p. 178), while Sundevall (1869, p. 596) received from his collector many specimens taken in winter. At present it appears to be rarer, as Bowdish (1902-3, p. 18) saw but one at Mayagüez, October 30, 1901. I saw a single bird on Vieques Island April 4.

MAGNOLIA WARBLER. *Dendroica magnolia* (Gmelin).
REINITA, BIJIRITA MANCHADA.

The magnolia warbler is a rare migrant and winter visitant. The only certain record is that of Bowdish (1902-3, p. 18), who found it at San Juan September 26, 1899, and Mayagüez December 26, 1900. Gundlach knew the bird merely from a drawing in the album of Bello.

PORTO RICAN YELLOW WARBLER. *Dendroica petechia bartholemica* Sundevall.
CANARIO DEL MANGLAR, REINITA.

The Porto Rican form of the yellow warbler, a common resident, has a peculiar distribution, being confined entirely to the coastal plain and coming inland along the courses of the rivers to the base of the foothills. It never goes farther, except around Quebradillas, where the birds were distributed over the high flats 300 or 400 feet above the sea. In December and January, in the region about San Juan, these birds were confined mainly to the mangroves and the narrow strips of bushes immediately back of the beaches, but by the first of February they began to appear inland more frequently and were common about Rio Piedras in shade trees near houses. Whether its distribution is similar in other portions of the island can only be determined by further observation. At Bayamon they were found in scanty growths of grass and weeds on the gravel bars in the Bayamon River. At the Laguna de Guanica there were no bushes or mangroves, so that the birds frequented reeds and clumps of marsh grass. In all the coast towns a pair or two nest in the plazas, if there are suitable trees. They are very quick and active. The song of these birds, like that of *Dendroica aestiva*, is loud and cheery, and the call note a sharp chip. From February to June, which corresponds to the breeding season, the males sing the whole day long. July 8 at Manati a young bird just from the nest was taken, and after this date they were common. The adults apparently remain paired throughout the year, as even the last of August at Cabo Rojo, when they were molting badly, male and female were invariably found together.

Food.—The 63 stomachs collected show nothing but animal matter (100 per cent). These represent the food from January to August, inclusive, in Porto Rico, Vieques, and Culebra Islands.

This species may be listed among the bird enemies of the mole cricket (*Scapteriscus didactylus*), as an adult male collected at the Laguna de Guanica on May 26 contained in its stomach a mandible and other remains of a changa. Other orthopteran remains (7.21 per cent) were present in 14 stomachs. Lantern flies (Fulgoridæ), present in this species again in large numbers (17.6 per cent), were detected in 28 stomachs. Other Homoptera (7.24 per cent) were largely cicadas (*Proarno hilaris*). Other bugs, partly predacious, though two stinkbugs and a few bug eggs are included, amount to 3.03 per cent. Longicorn beetles (2.7 per cent) were present in 5 stomachs, while small leaf-beetles (1.88 per cent) were taken 12 times. Two species of flea beetles (*Systema basalis* and *Chatocnema* sp.) were each taken by two birds. Small beetles of this group are found to be injurious almost invariably to some of the vegetables grown in fields and gardens. Click beetles (4.96 per cent) were great favorites in the mangrove swamps, and among the weevils (1.21 per cent) may be mentioned a shot-hole stalk-borer (*Xyleborus* sp.). Fireflies come to 1.99 per cent and miscellaneous Coleoptera to 1.88 per cent.

Diptera (8.16 per cent) were present in 16 stomachs, in one case a flesh fly (*Compsomyia macellaria*) that deposits its eggs in sores or injuries in the flesh of living animals, or even in the nostrils of man. The larvæ, known as screw worms, are much dreaded, especially in tropical countries, as in many cases their attack is known to be fatal. That this bird is active in the pursuit of insects is attested by the fact that moths were eaten by 18 birds, and these with caterpillars taken by 9 birds amount to 11.95 per cent. Ants make up 0.58 per cent and other Hymenoptera 8.72 per cent. These last were contained in 26 stomachs and were largely small insects of parasitic habits. A species of *Kapala*, which infests ants, was taken once and indeterminate chalcids were noted three times. A peculiar sawfly, with two-branched antennæ, was found in one stomach. Spiders (18.07 per cent) were eaten constantly and appear in 31 stomachs. Two dragon flies and two earwigs with a small portion of miscellaneous matter form the remainder (2.57 per cent).

In the foregoing outline of the food of this bird it will be seen that approximately 28 per cent of the bulk is made up of insects of a more or less beneficial nature, as spiders, parasitic Hymenoptera, dragon flies, and some bugs. Against these, however, stand the 70 per cent and more of other insects consumed, practically all of harmful species. Among these are some great pests, the lantern flies, nearly all of the beetles, Lepidoptera, and others. Thus the yellow warbler is one of man's friends.

The following insects were identified in these stomachs:

ORTHOPTERA.		COLEOPTERA—continued.	
<i>Scapteriscus didactylus</i>	1	<i>Cryptocephalus</i> sp.....	8
HEMIPTERA.		<i>Myochrous</i> sp.....	1
<i>Ormenis</i> sp.....	11	<i>Systema basalis</i>	2
<i>Proarno hilaris</i>	3	<i>Chatocnema</i> sp.....	2
COLEOPTERA.		<i>Mordellistena</i> sp.....	1
<i>Scymnus roseicollis</i>	1	<i>Xyleborus</i> sp.....	1
<i>Cryptorhopalum</i> sp.....	1	DIPTERA.	
<i>Monocrepidius</i> sp.....	8	<i>Compsomyia macellaria</i>	1
<i>Photinus vittatus</i>	3	HYMENOPTERA.	
<i>Photinus glaucus</i>	2	<i>Kapala</i> sp.....	1
<i>Leptostylus</i> sp.....	2		

NORTHERN PARULA WARBLER. *Compsothlypis americana usneæ* Brewster.
REINITA, PECHO DE ORO.

The parula warbler was the most common of the migrant warblers in Porto Rico. It is found everywhere in forest growth, and occurs frequently in mango trees in pastures. In the forest it is the noisiest of the birds that gather to scold an intruder, and is always active, working quickly through the limbs or catching insects on the wing. Bowditch (1902-3, p. 18) records the first fall birds October 25, 1901, and November 5, 1900, and in 1912 the last were observed near Salinas April 30. One was observed March 8 at 3,000 feet elevation on El Yunque. Migratory movement was apparent among them by February 14, and after this the birds were very restless, especially during early morning, and there was a tendency to work from east to west. In March and April there were distinct waves of migration.

Food.—In studying the food of the parula warbler 61 stomachs from Porto Rico were examined, representing the months from December to May, inclusive, and all parts of the region under discussion. Animal matter amounts to 97.7 and vegetable to 2.3 per cent. The vegetable matter consisted of seeds of small berries of the camaceæ (*Miconia prasina*) and others and was found in five stomachs collected in December, January, and February.

The animal food is of much more importance and includes a large number of insect pests. Lantern flies (*Fulgoridæ*) (19.09 per cent) were identified in 29 stomachs. These with other homopteran remains (6.85 per cent), partly of the same family and partly from closely allied groups, all of which are harmful, show that a little more than one-fourth of the entire food is composed of these pests. Other bugs (3.69 per cent) comprise small numbers of leaf bugs, species of the chinch bug family, stinkbugs, and a few predacious assassin bugs. The birds are fond of beetles, and this order supplies 22.53 per cent of the food, nearly all being injurious species. Ladybird beetles (1.36 per cent) were present in 14 stomachs. Longicorn beetles (1.68 per cent) were taken 11 times, and leaf beetles of several species (7.95 per cent) were eaten by 30 of these birds. The major portion belong to the abundant genus *Cryptocephalus*, and several species are represented. Darkling beetles figure as 1.01 per cent and skin beetles 0.45 per cent. Scarred-snout weevils were eaten by eight birds, and among these the coffee leaf-weevil (2.02 per cent) was taken three times at least. Other weevils (2.57 per cent) include two shot-hole stalk-borers, several curculios, and others. Miscellaneous beetle remains make up 5.49 per cent.

Ants (0.17 per cent) were eaten five times, while other Hymenoptera, all small species, come to 3.57 per cent. Flies were captured by five birds and amount to 1.19 per cent. In 18 stomachs were caterpillars, sometimes mere fragments of skin, and in four others occurred moths. These together comprise 10.44 per cent of the total food. Fragments of spiders (29.53 per cent) were identified in 29 stomachs. A small portion of miscellaneous animal matter amounts to 0.26 per cent.

From the tabulated data as presented above the beneficial insects, counting the large number of spiders, amount to practically 35 per cent, and harmful species form the rest of the bulk exclusive of the small percentage of vegetable matter. The bird is thus seen to be a beneficial species. In winter it is the most abundant of the warbler family on the island and frequents localities where it can do much good; so that while not resident, it is one of the most valuable of the regular migrants.

A list of identified material taken from these stomachs follows:

HEMIPTERA.		COLEOPTERA—continued.	
<i>Ormenis</i> sp.....	2	<i>Myochrous</i> sp.....	1
<i>Tettigonia</i> sp.....	1	<i>Ceratoma denticornis</i>	1
<i>Lecanium</i> sp.....	3	<i>Chætocnema</i> sp.....	4
COLEOPTERA.		<i>Zabrotes</i> sp.....	1
<i>Olibrus</i> sp.....	6	<i>Helops</i> sp.....	1
<i>Scymnus roseicollis</i>	5	<i>Lachnopus</i> sp.....	3
<i>Scymnillus</i> sp.....	8	<i>Euscepes porcellus</i>	1
<i>Hyperaspis apicalis</i>	2	<i>Pseudomus</i> sp.....	1
<i>Litargus</i> sp.....	1	<i>Platypus</i> sp.....	2
<i>Cryptorhopalum</i> sp.....	5	<i>Xyleborus</i> sp.....	2
<i>Photinus</i> sp.....	3	HYMENOPTERA.	
<i>Photinus vittatus</i>	1	<i>Wasmannia auropunctata</i>	1
<i>Ptinus</i> sp.....	1	ARACHNIDA.	
<i>Leptostylus</i> sp.....	7	<i>Tetragnatha</i> sp.....	1
<i>Cryptocephalus</i> sp.....	20	<i>Argyrodes</i> sp.....	1
<i>Cryptocephalus pusio</i>	9		
<i>Chlamys</i> sp.....	2		

BLACK AND WHITE WARBLER. *Mniotilta varia* (Linnæus).

REINITA, GUSANERO, TREPADORA.

The black and white warbler is a winter visitant to Porto Rico, Vieques, and Culebra Islands. The species was common the middle of December, though apparently migration was still going on, and the last bird for the spring was noted at Salinas April 30. This species frequents all forest growth and shade trees about houses, creeping up and down tree trunks and working through the limbs after insects.

Food.—In 11 stomachs which were critically examined animal matter amounts to 100 per cent. The months from December to April, with the exception of February, are represented in this small series. Earwigs were eaten by five birds and come to 8.5 per cent. Orthoptera are represented in four cases and make up 27.06 per cent. Walking sticks were taken twice and a grasshopper once. Lantern flies, found in three birds, amount to 8 per cent, and other bug remains to 0.75 per cent. Beetles form the largest portion of the food and are found in larger or smaller quantities in all the stomachs examined. Longicorn beetles come to 5.61 per cent, leaf beetles to 1.06 per cent, and darkling beetles to 1.37 per cent. Scarred-snout weevils were eaten by three birds and amount to 8.17 per cent, while other weevil remains were encountered in eight stomachs and total 19.58 per cent. Engraver beetles (*Platypus* sp.) were taken by this species, as well as by others previously mentioned. Other beetle remains come to 4.92 per cent. Lepidoptera (5.63 per cent) are represented by two moths, a caterpillar, and a pupa. Hymenoptera were taken in small numbers by two birds, but only comprise 0.56 per cent of the total. Spiders form 8.79 per cent.

The black and white warbler is thus a useful species. The large number of weevils destroyed by the few examined is noteworthy, as are the percentages denoting the quantities of Orthoptera, lantern flies, and miscellaneous beetles eaten.

The following were identified in these stomachs:

HEMIPTERA.		COLEOPTERA—continued.	
<i>Ormenis</i> sp.....	1	<i>Lema</i> sp.....	1
COLEOPTERA.		<i>Cryptocephalus</i> sp.....	1
<i>Endeitoma granulata</i>	1	<i>Metachroma</i> sp.....	1
<i>Aulonium bidentatum</i>	1	<i>Platydemia virens</i>	1
<i>Leptostylus</i> sp.....	1	<i>Helops</i> sp.....	1
		<i>Euscepes porcellus</i>	3
		<i>Platypus</i> sp.....	3

PORTO RICAN BANANAQUIT, PORTO RICAN HONEY CREEPER. *Cæreba portoricensis* (Bryant).
REINITA, REINA, GUSANERO.

The honey creeper was a common resident in all the localities visited. In Porto Rico it is without question the most abundant bird, being found everywhere in the mangroves lining lagoons and bays, along maya hedges, through the cane fields, in mango trees in the pastures, in coffee plantations, thickets, and small forests, seemingly being able to adapt itself to all conditions. It is the only bird common in the dense, humid forests clothing the higher slopes of El Yunque, and the species is equally common on the dry south coast, where rains are infrequent. Honey creepers are very quick and active, and when resting for an instant flit the wings rapidly with a kinglelike motion. In the maya hedges they work quickly along, going out frequently into the cane fields. It is one of the few birds common in coffee plantations, far outnumbering all the other species found there. These creepers are very tame and trusting, coming about houses, searching the eaves for spiders, and even entering open doors and windows. In the little cafetins in the barrios it is a common practice to place sirup on the counter for them, and a pair will visit this supply daily.

The song of this bird is incessant and is an insectlike trill that may be likened to the syllables *zee-e-e-e swees se tee*, the first part given slowly in a thin, high tone and the last more rapidly. In the dark forests of El Yunque this was the only song heard. Nothing appears to daunt them. Near Adjuntas, after a cloudburst, where the torrents of rain were accompanied by violent, shifting winds, the honey creepers were singing cheerfully the instant the heaviest part of the downpour was over. The young begin singing as soon as they are fully feathered and frequently are breeding before they have lost the juvenal plumage, when they can not be more than 6 or 7 months old.

The nesting season extends without break throughout the year, though nests are most abundant from February to June. Several broods are raised; how many can be told only by extended observations of one pair. The nests are common and many are built in exposed localities. They are globular affairs, placed at the tips of limbs in a semipendant fashion, from 5 to 30 feet from the ground, and built of weeds, leaves, and grasses, lined with finer material. The opening is always underneath. Both sexes assist in building, bringing straws and other material and fixing them in place, at first forming merely a rounded mass. Although the male is allowed to assist, he brings material only when the female is absent, as, should she catch him in the nest, he is immediately driven out.

The nests, when empty, are used as sleeping quarters, and these birds sleep late, not coming out in the morning until half an hour after other birds have become active. The usual number of young is two or three. The nests of this species should be protected rigidly, as hundreds of eggs are now destroyed wantonly by boys.

All the flowering plants are searched by honey creepers in their quest for food. The molinillo (*Leonotis* sp.) was perhaps visited most frequently, the birds clinging to the rounded flower heads and probing each one in turn. The muñeco (*Cordia collococca*) and bucare (*Erythrina* sp.) also, when in blossom, proved a great attraction. The flowers of the banana contain much nectar, and these are visited often. The birds are said occasionally to pierce ripe bananas, but as the bunches are usually cut while green, the damage is negligible. One taken near Cayey January 17, 1912, had the throat filled with pulp of red raspberries (*Rubus rosifolius*), and it was not unusual to find clear nectar in the esophagus. Near Rio Piedras one visited a ripe guanabano (*Anona muricata*) that had been torn open by a spindalis, and ate for nearly five minutes, hang-

ing head down from a twig above and pulling and nibbling at the inside of the fruit. Other undamaged fruit in the same tree was not touched even after the one that was already open was removed. There is some complaint among fruit growers that this species pricks and destroys oranges but though much time was spent in the groves nothing of this kind was seen, the nearest approach to it being when fully ripe fruit had been opened by other agents, then the honey creepers visited it for the juice. Those seen in citrus groves were invariably feeding on insects.

Food.—Because of the complaints made by many people against these birds much time was devoted to watching them, and a considerable number were collected. One hundred and forty-nine stomachs were examined, and in these animal matter amounted to 97.56 per cent and vegetable to 2.44 per cent. These birds were collected on Porto Rico, Vieques, and Culebra, in the months from December to August, inclusive. The vegetable matter consisted of seeds in six stomachs (in one case of *Chenopodium* sp.) and of vegetable fiber in three others, so that in no case did it have any particular significance. The stomach itself is very small in proportion to the size of the bird, appearing merely as a knot at the juncture of the esophagus and intestine. The birds undoubtedly feed to a great extent upon nectar and other sweets, but just how large a portion of their nutriment is secured from this source can not be determined. However, each stomach, small as it was, was usually filled with animal matter, and from it can be determined the economic status of the species. Lantern flies (*Fulgoridæ*) appeared in 33 instances and amount to 14.52 per cent. In two cases they form the entire bulk of the stomach contents, and large percentages occur in several. Only one other bug was identified in this series of stomachs. Leaf beetles, among which were several flea beetles, amount to 2.11 per cent, and longicorn beetles to 0.35 per cent. Ladybird beetles were found in 10 stomachs and constitute 1.87 per cent. They were the only beneficial beetles eaten. Weevils are well represented, coffee leaf-weevils, found 10 times, coming to 1.79 per cent. Curculios and billbugs comprise 0.8 per cent, engraver beetles 1.55 per cent, and a few miscellaneous weevils 0.47 per cent. Beetle remains other than those mentioned above figure as 2.89 per cent.

In no less than 96 stomachs were bits of caterpillars, while one other contained a pupa and a moth. These form 37.56 per cent, the largest item in the food of the bird. Nearly all the caterpillars were small and very young. They form much of the food through all of the months represented, the maximum, 46.42 per cent, being contained in a collection of 36 stomachs secured in March. Remains of flies were encountered in 13 stomachs and come to 1.26 per cent, and ants in 17 birds amount to 1.28 per cent. Bits of other Hymenoptera (4.65 per cent) were found in 16 stomachs. They come mainly from the small parasitic groups, though a few from other families are represented. Spiders, nearly all young ones, and therefore indeterminate as to genus and species, were eaten by 82 of these birds and a pseudoscorpion by one. These comprise 25.89 per cent of the bulk. Miscellaneous matter (0.58 per cent) includes a snail and some insect eggs. An interesting result in these examinations was the finding in three stomachs of Thysanoptera, which were in two instances definitely identified (*Ommatothrips* n. sp.). These are insects of great economic importance in many cases, and birds eating them perform good service. They are so small and so fragile that they would be rapidly digested and eliminated from a stomach.

One-third of the food of the honey creeper, as shown in the discussion above, is composed of beneficial insects, more than .25 per cent being spiders, some of which may be of doubtful value. Passing over the 2.44 per cent of vegetable matter, the remainder is composed entirely of harmful species. Lantern flies injurious to nearly all kinds of vegetation, several kinds of weevils, and large

numbers of caterpillars are eaten greedily, while ants, flies, and thrips are taken in less number. The list includes many serious pests, against the attacks of which the agriculturist must guard, and in destroying them the bird is performing excellent service. Reports of the destructiveness of the honey creeper to oranges seem unsubstantiated, but if individuals form this habit they should be destroyed. Otherwise the species should be protected and encouraged in all localities. The following were identified in these stomachs:

THYSANOPTERA.		COLEOPTERA—continued.	
<i>Ommatothrips</i> n. sp.-----	2	<i>Phytomerus</i> sp.-----	2
HEMIPTERA.		<i>Cryptocephalus</i> sp.-----	1
<i>Ormenis</i> sp.-----	7	<i>Myochrous</i> sp.-----	1
COLEOPTERA.		<i>Lachnopus</i> sp.-----	10
<i>Scymnus roseicollis</i> -----	1	<i>Euscapes porcellus</i> -----	1
<i>Scymnillus</i> sp.-----	5	<i>Phyllotrox</i> sp.-----	2
<i>Leptostylus</i> sp.-----	3	<i>Caulophilus</i> sp.-----	1
<i>Lema</i> sp.-----	1	<i>Caulophilus latinasus</i> -----	1
		<i>Platypus</i> sp.-----	3
		<i>Xyleborus</i> sp.-----	2
		<i>Xyleborus inermis</i> -----	1

HOODED WEAVER FINCH. *Spermestes cucullata* (Swainson).

DIABLITO, CHUPADOR DE ARROZ, GORRION.

The hooded weaver finch, an African species, has become naturalized in Porto Rico, and is a common resident up to an altitude of 600 feet. Above that it was noted only at Cayey (1,275 feet) and Adjuntas (1,550 feet). It was evidently introduced many years ago, as Bryant (1866, p. 254) mentions that several specimens were taken on the island in the sixties. This species is usually found in small flocks of from 10 to 25 and frequents open banks of streams, borders of fields, and grass-grown pastures where food is abundant. Near Cabo Rojo they were very common, and flocks of several hundred were encountered. On the ground these tiny birds feed close together, clustering on the ripening heads of malojillo (*Panicum* sp.), busily eating. When flushed they rise in a close flock with low churring notes, and fly only a short distance to a tree, where the whole flock divides into twos and threes, the birds sidling along the limbs until they are as close together as possible. Near Cabo Rojo in August the young gathered in large flocks, and were evidently roosting at night in dense mango trees.

In May they divide into pairs and breed. A nest found near Yabucoa May 10 was built in a small tree on a steep slope, where the structure was visible from all sides. It was located about 6 feet from the ground, and was built of grass stems 8 or 10 inches long and well thatched in, but with the ends projecting crisscross in every direction. The top was arched over, but the nest had a very untidy appearance. It contained one young bird about 3 days old, and three eggs on the point of hatching. The eggs were opaque white and in shape were elongate elliptical.

Near Cabo Rojo the last of August these birds were preparing to raise a second brood, as the first were old enough to care for themselves. At Comerio they were feeding in seed-tobacco fields, where all the seed heads had not been collected, but unless very abundant they would not do damage.

Food.—In January, February, May, July, and August, 33 stomachs of this little weaver finch were collected, and with many of them the gullet was preserved also, as it was usually distended with seeds. The only animal matter in these was the elytron of a rove beetle. Large quantities of sand were found in all, and in a few were bits of snail shell, unquestionably picked up as an aid to digestion. Seeds of various grasses and a few of sedge constitute the entire

contents. These are nearly always shelled before swallowing and in the gizzard are soon ground up and digested. In eating these grass seeds the birds can be accused of no damage, though formerly they were said to injure rice when it was still soft. For their ordinary food, however, they prefer smaller seeds than rice, and as rice is little cultivated now because of the ravages of the changa this weaver finch seems to be a neutral species, though it destroys numbers of crab grass seeds. At times it may feed on seeds desired for planting, and then should be discouraged. A list of seeds eaten follows:

Crab grass (<i>Syntherisma sanguinalis</i>)	5	Panic grass (<i>Panicum</i> sp.)	2
Ichnanthus (<i>Ichnanthus pallens</i>)	6	Malojillo (<i>Panicum fasciculatum</i>)	17
Egyptian grass (<i>Dactyloctenium aegyptium</i>)	3	Paspalum (<i>Paspalum</i> sp.)	3
		Paspalum (<i>Paspalum millegrana</i>)	20
Smut grass (<i>Sporobolus indicus</i>)	6	Fimbristylis (<i>Fimbristylis</i> sp.)	1

SCARLET-CHEEKED WEAVER FINCH. *Amandava melopoda* (Vieillot).
VETERANO, BENGALI, GORRION.

Another African species that has been introduced and naturalized in Porto Rico is the scarlet-cheeked weaver finch. Gundlach (1878, p. 206) found them abundant in 1874, and is the first to mention them. They are now found in the coastal regions from Mayagüez to Yauco, which is practically the range given by Gundlach 35 years ago, except that he recorded them north to Añasco. They were seen at Yauco May 16 to 28; Cabo Rojo, August 24 to 31; and at Mayagüez, June 6. The northern half of their range is very humid, while at Yauco and below Cabo Rojo it is equally dry. These birds frequent marshy growths and dense thorny thickets of rallo (*Vachellia* sp.), an acacia, and cane fields. They are spirited little birds with quick, nervous movements and when alarmed call continually. On the wing the long tail and short wings give them a quick, tilting flight, and they seldom fly far. When feeding they spread out somewhat, but when excited all bunch up, peering through the limbs, and then move away, keeping well under cover. In the middle of the day they feed on the ground, in patches of shade under bushes. In the cane fields they flush with quick calls, fly a few yards, and then drop back out of sight.

The ordinary call note is a low *tsee tsee tsee* and a low chattering call. Near Cabo Rojo, August 30, one female was seen feeding nearly grown young, regurgitating softened grass seeds from her throat to give to them. Bowditch (1902-3, p. 13) notes breeding birds taken May 23 and 30, presumably from Mayagüez.

Food.—In 19 stomachs of this odd exotic, collected at Yauco in May and Cabo Rojo in August, I found vegetable food only, with small percentages of sand as an aid in digestion. Grass seeds of several species furnished the bulk of the food and were nearly always neatly shelled. A few amaranth seeds were found, and these were swallowed entire, the smooth hard surface of the seed not permitting them to be readily split open, though the three-sided seeds of a sedge (*Carex* sp.) were neatly divested of their covering. Two immature birds had swallowed large quantities of grass seeds without hulling them, and occasionally adults ate small seeds in this condition.

These weaver finches destroy small numbers of seeds of noxious weeds, though they prefer panic grass, but as they take no insects they are of little economic importance.

The following list shows the seeds fed upon:

Crab grass (<i>Syntherisma sanguinalis</i>)	5	Paspalum (<i>Paspalum millegrana</i>)	5
Smut grass (<i>Sporobolus indicus</i>)	5	Sedge (<i>Carex</i> sp.)	1
Ichnanthus (<i>Ichnanthus pallens</i>)	3	Amaranth (<i>Amaranthus</i> sp.)	5
Malojillo (<i>Panicum fasciculatum</i>)	6		

BOBOLINK. *Dolichonyx oryzivorus* (Linnaeus).

CHAMBERGO.

The bobolink is a rare migrant. Pelzeln (1871, p. 199, footnote) says that a specimen received from the Paris Museum is marked Porto Rico, and Gundlach¹ says that it has been taken on Vieques Island, where previously recorded by Cory (1892, p. 110).

YELLOW-SHOULDERED BLACKBIRD. *Agelaius xanthomus* (Scater).

MARIQUITA, CAPITAN.

The yellow-shouldered blackbird is a common resident in Porto Rico. There appear to be a few of these birds on Mona Island, as Bowdish (1902-3, p. 12) recorded one, and Cory (1892a, p. 229) received two collected by W. W. Brown, jr., in February and March, 1892. In Porto Rico the species is found mainly below an altitude of 800 feet, and is most abundant in the coastal region, following inland along the open valleys of the larger streams. Lares (1,200 feet) was the highest point at which they were observed, none being seen in the high central mountain range. In fall, winter, and spring this species moves over the country in small flocks, returning at nightfall to some clump of trees or mangroves to roost, so that it is common to see them flying back and forth morning and evening. The flight at such times is direct, though undulating, and an occasional flash of yellow shows on the wing. In the mangrove swamps a small party frequently feeds in close array on the wet ground, or single individuals clamber through the branches absorbed in their search for food. Often they are seen climbing actively up and down the long fronds of the coconut palms, in oriole fashion, or walking sedately among the cattle in pastures.

The common call note is a sharp *chick* that is indistinguishable from that of the Porto Rican oriole, and a low *chuck* is often heard. About the nests they have the sharp, staccato, scolding notes of the red-winged blackbird of the North, given as they circle and wheel overhead. The males do not sing a great deal, though odd, wheezy, or reedlike notes, resembling those of the yellow-headed blackbird, are sometimes heard.

The breeding season is in May and June, sometimes as early as March, and the young are usually out of the nest by the end of June. The nests of this species appear always to be built in coconut or royal palms, the birds nesting, as a rule, in small colonies or sometimes in pairs. When the nest is in a royal palm, the male spends most of his time on the tall projecting spike in the crown, where he postures with drooping wings and spread tail, but sings very little. When alarmed, the female flies up and clings to the side of the spike, just below him, both scolding vigorously. All the nests observed were in the axils of the long leaves. The birds feed near the nest, walking about on the ground, and sometimes wading in shallow water. As soon as the young leave the nest, all gather in small flocks, at first remaining near the nesting colony, but as they get stronger on the wing going farther afield. At this season they avoid the intense midday heat by frequenting coffee plantations, clumps of bamboo, and shaded perches.

In mixed flocks with the Porto Rican grackle, this species feeds in newly plowed fields and in cane fields while the growth is small, following the plow for the grubs and insects exposed. In this way they do much good. Around Manati large flocks of old and young frequent the citrus groves, feeding on the ground and flying up to perch in close flocks in the trees, the dead limbs being preferred. In spring, with the other blackbirds, they frequent the bucare trees (*Erythrina* sp.), probing the handsome blossoms for their nectar.

¹ Ornithologia Cubana, 1893, p. 118.

Food.—From January to July, inclusive, 55 stomachs of this bird were collected and later examined in the laboratory. In the primary allotment animal food amounted to 90.1 per cent and vegetable to 9.9 per cent for the period under consideration. Weevils, other beetles, cutworms, and caterpillars comprise by far the greater bulk of the animal matter, while of the vegetable food a little more than half is composed of corn.

Animal food.—Feeding upon the ground, as other blackbirds do, and in the trees, as its relatives the orioles do, a wide range of animal food is secured by this bird. Orthopterous remains (1.95 per cent) in six birds are formed largely of grasshopper eggs and the oöthecæ of roaches, though remains of adults were found. Earwigs (Forficulidæ) (1.37 per cent) secured in searching oriolelike through the branches of trees were eaten by five birds. Homopterous remains (5.7 per cent) are composed of tree hoppers and lantern flies, with bits of a cicada. Other bug remains (3.36 per cent) are of predatory species in part at least. Leaf beetles constitute only 1.69 per cent, though present in 18 instances. Flea beetles and tortoise beetles were represented, though the larger number were unknown species of the genus *Cryptocephalus*. The cane root-boring weevil (*Diaprepes spengleri*) was eaten nine times and amounts to 1.72 per cent. Other scarred-snout beetles to which family this pest belongs comprise 10.15 per cent and were found in 16 of the gizzards. Among them were several coffee leaf-weevils (*Lachnopus* sp.). Curculios total 2.13 per cent and other weevil remains 1.92 per cent, so that weevils as a whole constitute nearly one-sixth of the entire food. Cerambycidæ (0.81 per cent) were taken in small quantities, and miscellaneous Coleoptera figure as 16.79 per cent.

Caterpillars were found in 30 stomachs, lepidopterous pupæ in 3, and a moth in 1, all forming 28.32 per cent. A large part of those first enumerated were cutworms, picked up in cultivated fields. The greatest quantities were eaten in January and February. The remains of Hymenoptera (1.03 per cent) include a number of ants and a wasp, as well as some unidentified fragments. Diptera (3.65 per cent) were taken sporadically, the largest number being secured in January. Spiders eaten by 13 birds amount to 7.83 per cent, snails found in eight instances figure as 1.56 per cent, while miscellaneous animal matter forms 0.43 per cent. A list of identified species follows:

HEMIPTERA.		COLEOPTERA—continued.	
<i>Proarno hilaris</i>	1	<i>Cryptocephalus</i> sp.....	18
<i>Phymata</i> sp.....	1	<i>Systema basalis</i>	2
		<i>Coptocycla signifera</i>	1
		<i>Anthicus floralis</i>	1
		<i>Diaprepes spengleri</i>	9
		<i>Lachnopus</i> sp.....	6
<i>Monocrepidius bifoveatus</i>	1	<i>Euscapes porcellus</i>	1
<i>Photinus glaucus</i>	3	<i>Metamasius hemipterus</i>	1
<i>Eburia</i> sp.....	1		

Vegetable food.—More than one-half (5.73 per cent) of the vegetable food is composed of corn taken entirely in May and June. For June it totals 36.87 per cent and was present in 10 of the 15 stomachs examined for that month. In May only 2 birds in 18 had taken any. In June flocks of these birds were feeding in ripening fields of corn near Lares. The adults were feeding their young out of the nest on the soft kernels taken from the ear. Though the birds were not seen actually eating the grain, the terminal kernels of a small number of ears in each field were missing, and bits of the grain were found in the bills and throats of some of the birds shot. Two birds collected in a cornfield near Ciales on July 17 had not touched the grain.

Other vegetable food consisted of seeds of grass, a few unidentified seeds, 3.71 per cent in all, and a small quantity (0.35 per cent) of vegetable rubbish.

Summary.—Roughly estimated, nine-tenths of the food of the mariquita is levied from the animal kingdom and large numbers of harmful insects are destroyed. Weevils especially are favorites, and comprise several serious pests of sugar cane, coffee, and other crops. Cutworms, too, are much relished, and a host of other forms, among which only spiders may be considered useful, make up the remainder. Of the remaining one-tenth of vegetable matter a little more than half is composed of corn taken from the ear when still in the milk. For the entire year this is a small amount, but during June some damage is done locally, and in such cases the blackbirds should be driven out by shooting or other means. In some instances it was found that the birds, though flocking in cornfields, did not touch the grain, so that before disturbing them there should be evidence of sufficient damage to warrant it. Throughout the season as a whole this blackbird is beneficial, and should be allowed a small toll of grain as part payment for its usefulness. Care should be taken not to mistake the depredations of rats in the cornfields for the work of the blackbirds. Rats are in some cases very destructive to grain in localities frequented by the blackbirds. The blackbird merely pecks open the end of the ear and pulls off the kernels, while the rat gnaws off the husks, dropping a pile of refuse to the ground below and frequently destroying half the ear.

PORTO RICAN ORIOLE. *Icterus portoricensis* (Bryant).
CALANDRA, CALANDRIA.

The oriole is resident on the island of Porto Rico. It is common in the coconut palms near the coast, and inland it frequents coffee plantations and second-growth forests, where, swinging head down, it finds and destroys many caterpillars. It is rather wild at times and keeps well concealed, and again comes into shade trees about the houses. This bird has the most beautiful song of all the Porto Rican species—a clear whistle of several notes, pitched rather high. It sings mainly in the morning and evening, and is one of the few birds heard at daybreak. The ordinary call note is an oriolelike *chick* or *chuck*, and the birds also have a thin, high note like *pe-ee*, resembling the call note of the goldfinch or siskin.

The breeding season extends from the first of May to the middle of July, and after the middle of June young in first plumage are common. The adults begin to molt then. This species breeds while in first-year plumage, and several pied specimens were taken. The only nest located was in a grove of coconut palms north of Manati, on July 8. It swung from the underside of one of the long leaves, and was supported under the center of the rib by four radiating "straps," firmly attached, leaving only a small space between it and the underside of the midrib to serve as an entrance. It appeared to be woven strongly of fibrous materials.

The oriole is very fond of the sweet flower juices of plants and trees, the bucare (*Erythrina* sp.) being visited frequently when in blossom, while the abundant nectar of the banana is a great attraction, several birds visiting a single flower in rapid succession. Near Aibonito the birds were seen eating the pulp and juice of overripe wild sweet oranges (*chinas*) and had opened half a dozen on one tree. As the fruit in cultivated groves is picked long before it reaches this stage no damage results.

Food.—From January to August, 71 stomachs were collected and on detailed examination these show 99.84 per cent of animal matter. Two birds had secured a little vegetable rubbish and one had eaten the hard flinty seed of a grass (*Olyra latifolia*), which in all amounts to only 0.16 per cent. Earwigs, some of them of large size, were found in 40 stomachs, though often only the curious nipperlike caudal forceps remained after the processes of digestion.

They amount to 24.36 per cent of the total, and as their habits in the Tropics seem little known must be regarded as neutral species. Four of the birds secured in April and May had eaten the mole cricket (*Scapteriscus didactylus*), though in small quantity (0.21 per cent). Other Orthoptera (7.2 per cent) were eaten 18 times and were composed in great part of other crickets, roaches, numbers of roach egg cases, and a few grasshoppers and their eggs. Cicadas, found in nine stomachs, form a considerable share of the bulk (7.56 per cent). Other bug remains, a stinkbug, tree hoppers, and some other fragments, total 1.36 per cent.

Weevils form one-seventh of the entire food, and among them the scarred-snout beetles are the best represented (12.89 per cent). The cane root-borer (*Diaprepes spengleri*) was eaten 3 times, the coffee leaf-weevil 11, and members of this family were identified in 30 stomachs. Curculios come to 0.6 per cent and miscellaneous Rhyncophora to 1.72 per cent. A few leaf beetles were eaten regularly (1.22 per cent) and darkling beetles were taken in small numbers (1.40 per cent). Miscellaneous matter (1.63 per cent) consisted of a scarabæid, a firefly, four click beetles, and a few longicorns and buprestids. Lepidoptera (4.3 per cent) were well represented by caterpillars taken by 16 birds, and a moth and a pupal case in one instance each. Hymenoptera composed of ants, wasps, and wild bees comprise 2.44 per cent, and flies 0.22 per cent. Forty birds had eaten spiders and one a scorpion, which come to 31.67 per cent. Miscellaneous matter, largely vertebrate, amounts to 1.06 per cent. Small tree toads were secured three times and one little lizard was eaten.

With the exception of spiders, which form a little less than one-third of the food, and a few vertebrates, the animals destroyed by the Porto Rican oriole are in the main harmful species. In searching through the trees the bird secures numerous scarred-snout beetles and other weevils, a group which contains some of the most serious pests of the region. Grasshoppers, roaches, crickets, and caterpillars are taken in numbers. The oriole is one of the beneficial birds frequenting coffee plantations and, having abundant shelter and building inaccessible nests, the bird will continue to hold its own.

The following were determined in the stomachs examined:

EUPLEXOPTERA.		COLEOPTERA—continued.	
<i>Phaulx albipes</i> -----	1	<i>Metachroma</i> sp-----	2
ORTHOPTERA.		<i>Metachroma lituratum</i> -----	1
<i>Orocharis</i> sp-----	1	<i>Coptocycla signifera</i> -----	1
<i>Anurogryllus muticus</i> -----	1	<i>Platydema</i> sp-----	4
<i>Scapteriscus didactylus</i> -----	4	<i>Helops</i> sp-----	1
HEMIPTERA.		<i>Diaprepes spengleri</i> -----	3
<i>Proarno hilaris</i> -----	3	<i>Lachnopus</i> sp-----	11
<i>Lecanium</i> sp-----	1	<i>Euscepes porcellus</i> -----	3
COLEOPTERA.		<i>Metamasius hemipterus</i> -----	1
<i>Europs apicalis</i> -----	1	HYMENOPTERA.	
<i>Photinus glaucus</i> -----	1	<i>Solenopsis geminata</i> -----	1
<i>Cryptocephalus</i> sp-----	3	VERTEBRATA.	
		<i>Eleutherodactylus</i> sp-----	3
		<i>Anolis</i> sp-----	1

TROUPIAL. *Icterus icterus* (Linnaeus).

TROUPIAL.

Gundlach (1878, p. 209) notes the troupiál, an exotic species, as naturalized near Quebradillas, and says that its food consists of various wild fruits and the

seeds of the royal palm. The bird is known to many of the Porto Ricans and at one time must have been fairly common. Now, however, it is very rare if not actually extinct. An oriole seen below Aibonito January 5, was thought to be this species, but identification was not certain. All the reports regarding its occurrence come from the western end of the island. The species is commonly kept as a cage bird, and probably has been introduced in this manner.

PORTO RICAN BLACKBIRD. *Holquiscalus brachypterus* (Cassin).

MOZAMBIQUE, CHANGO.

(PLATES VIII and IX.)

The Porto Rican blackbird is one of the characteristic birds of the island, being found wherever there are cultivated fields. In the lowlands, below 500 feet altitude, it is the most common bird, and above that it occurs in small numbers.

The birds are found ordinarily in small flocks of from 3 or 4 to 25, feeding on the ground in the pastures or cultivated fields. The males strut about, holding the head and tail high, calling squeakily, while the females are more preoccupied searching busily for food. In flight the V-shape of the tail is much exaggerated, the birds seeming almost deformed. In rising this is rather a hindrance to them, and in flying up into a palm they sometimes go beyond the tree and then come back, not being able to rise at a sharp angle. Their favorite perches are the royal and coconut palms, where they spend much time, walking up and down the broad leaf stems or sitting quietly in their shade. The ordinary call note is a gracklike *chuck* or a thin high *tee tee tee*, and the song may be represented by the syllables *K'see ah—h—h*, rather a wheezy effort, given with the wings spread and the tail deeply V-shaped.

The breeding season extends from the 1st of May until the 10th of July, the birds usually nesting in colonies in royal or coconut palms, though at times an isolated jobo tree (*Spondias lutea*) is chosen. The royal palm is, however, the favorite location. The nests are constructed in the large seed clusters and at the bases of the long leaves, often in close proximity. The birds were continually flying back and forth about the nests calling, singing, and posturing, making a scene of the greatest animation. Nest construction is carried on by the females, though the males always accompany them, strutting about on the ground and driving other intruding males from the chosen nesting site. Incubation, too, falls to the lot of the female, her spouse following her expeditions for food, but when the young are hatched both sexes care for them. After the middle of June the young commonly follow their parents, teasing for food, and when unnoticed protest vigorously. In August these family parties join in small flocks, remaining together until the next year. The flocks feed in the cultivated fields, pastures, or sometimes on the gravel bars of streams, where occasionally they wade in the shallow water, turning over the leaves for aquatic insects or, standing in water up to their bodies, splash and flutter in bathing.

This species is widely recognized as the most beneficial on the island, and fortunately it is also one of the most common. While the cane and tobacco fields are being prepared for planting, flocks of the birds follow the plow, feeding on the insects exposed in the overturned furrows. Even when the cane is well grown they follow the cultivator through the rows. In the breeding season it is common to see three or four fly from the low-lying fields inland into the foothills with a white grub shining in each bill. On the ground they walk rapidly along, peering from side to side and following the working peons closely.

After the breeding season old and young were observed feeding also on wild fruits, among which were the following: Icaco (*Chrysobalanus* sp.), sapalo (*Palicourea riparia*), and moral (*Cordia nitida*). In spring the adults were

seen taking the nectar from the bucare (*Erythrina* sp.) and the muñeco (*Cordia collococca*). Frequently birds had the throat full of this honey and the feathers of the head yellow with pollen. The manzanillo (*Hippomane manchinella*) also was eaten to some extent.

Food.—The blackbird or chango is one of the best-known birds of Porto Rico, and its usefulness is almost universally recognized. Some of the current ideas of its food, based on observation alone, are mistaken, but so much good is done in other ways that the chango is entitled to a high place in the class of beneficial species. From December to August, 98 of these birds were collected in all parts of Porto Rico and in Vieques, and the contents of their stomachs later were scrutinized carefully. Animal food formed 93.38 per cent and vegetable 6.62 per cent. Blackbirds everywhere are recognized as almost omnivorous, and this species is no exception to the rule, all living creatures of small size being eaten.

Animal food.—Though commonly considered one of the greatest enemies of the mole cricket (*Scapteriscus didactylus*), remains of this insect were found in only eight of the birds (0.21 per cent), most of them being eaten in July. The changas taken are nearly all nymphs. Remains of other Orthoptera (19.34 per cent) were found in 42 stomachs and comprise adults of grasshoppers, locusts, and crickets, with a few eggs of roaches, walking sticks, and others. Insects of this class are common in the pastures frequented by the blackbird and form an abundant food supply. Bugs of the homopterous group (2.02 per cent) are composed in great part of cicadas (*Proarno hilaris*), with a few lantern flies. Stinkbugs (3.32 per cent) were eaten 17 times, and miscellaneous bug remains come to 1.11 per cent. Adult May beetles (*Lachnosterna* sp.) were found in 2 instances and larval scarabæids—white grubs—in 11, all amounting to 1.42 per cent. In 23 birds collected in May, largely in cane fields under cultivation, these form 9.47 per cent, and it is under such conditions that insects of this group are exposed to attack. Large numbers of the adult cane root-boring weevil were destroyed, this insect being identified in 39 stomachs. For the entire period this weevil amounts to 9.69 per cent, while for the months of April and May the bulk of it came to 26.67 per cent and 32.13 per cent, respectively. Remains of 11 were taken from one gizzard and from 3 to 6 were not unusual. The coffee leaf-weevil (*Lachnopus* sp.) was taken by 23 birds and amounts to 1.61 per cent. And though only 13 birds had eaten the slender-beaked weevil stalk-borer (*Metamasius hemipterus*), it constitutes 5.44 per cent. This weevil was secured in March and in the months from May to August, inclusive. Mixed remains of curculios and other weevils total 1.23 per cent and other beetle remains 1.06 per cent.

Lepidopterous remains (11.15 per cent) figure largely in the food and occur in all the months except April. Thirty-nine birds ate caterpillars and six had captured moths. One stomach contained 16 cutworms as well as 3 adult cane root-boring weevils. Diptera (0.16 per cent) were present in small numbers and Hymenoptera (1.11 per cent) occurred frequently. This group, with only two exceptions, was represented by wasps and considerable numbers of ants, among which fire ants (*Solenopsis geminata*) occurred three times. Spiders were found in 30 gizzards and mites in 1. Two birds had eaten cattle ticks (*Margaropus annulatus*). One of these, taken in a brush-filled pasture on Vieques Island on March 21, contained 35 ticks, and the other from Cabo Rojo, killed on August 31, had eaten 12 ticks, all greatly distended with blood, so that in this case they were undoubtedly picked from some animal. Snails (*Subulina* sp. and *Planorbis* sp.) were eaten regularly and comprise 6.02 per cent of the total. Amphibian remains (5.74 per cent) were encountered in 12 stomachs and were composed of both the common frog and little tree toad. Lizards (16.04 per cent) were found

in 34 stomachs. The ameiva was found twice, the other remains being those of small anolis. Miscellaneous animal matter comes to 1 per cent.

A list of identified animal matter follows:

ORTHOPTERA.		LEPIDOPTERA.	
<i>Neoconocephalus macropterus</i> -----	1	<i>Alabama argillacea</i> -----	2
<i>Anurogryllus muticus</i> -----	4		
<i>Scapteriscus didactylus</i> -----	8	HYMENOPTERA.	
HEMIPTERA.		<i>Pheidole</i> sp-----	1
<i>Ormenis</i> sp-----	1	<i>Pheidole fallax</i> var. <i>antillensis</i> -----	1
<i>Proarno hilaris</i> -----	8	<i>Solenopsis geminata</i> -----	3
<i>Emesa</i> sp-----	2	<i>Strumigenys rogeri</i> -----	1
<i>Margarodes formicarum</i> -----	1		
<i>Lecanium</i> sp-----	1	ARACHNIDA.	
COLEOPTERA.		<i>Margaropus annulatus</i> -----	2
<i>Hyperaspis apicalis</i> -----	1		
<i>Monocrepidius bifoveatus</i> -----	1	MOLLUSCA.	
<i>Chrysobothris</i> sp-----	1	<i>Subulina</i> sp-----	16
<i>Lachnosterna</i> sp-----	2	<i>Planorbis</i> sp-----	9
<i>Cryptocephalus</i> sp-----	1		
<i>Systema basalis</i> -----	2	VERTEBRATA.	
<i>Lachnopus</i> sp-----	23	<i>Leptodactylus</i> sp-----	2
<i>Diaprepes spengleri</i> -----	39	<i>Leptodactylus albilabris</i> -----	5
<i>Euscepes porcellus</i> -----	4	<i>Eleutherodactylus</i> sp-----	3
<i>Chalcodermus</i> sp-----	1	<i>Ameiva exul</i> -----	2
<i>Chalcodermus pupillatus</i> -----	1	<i>Anolis</i> sp-----	26
<i>Baris torquatus</i> -----	1		
<i>Metamasius hemipterus</i> -----	13		

Vegetable food.—Of the 6.62 per cent vegetable matter, 2.19 per cent is composed of corn. This was eaten by 13 of the 98 birds examined and was secured mainly in July, when it amounts to 11.82 per cent. The grain taken was consumed in December, April, and July. Seeds (largely grass seeds) amount to 2.96 per cent and vegetable rubbish comes to 1.45 per cent.

A list of identified species is appended:

Crab grass (<i>Syntherisma sanguinalis</i>)--	1	Wild fig (<i>Ficus</i> sp.)-----	2
Smut grass (<i>Sporobolus indicus</i>)-----	1	Amaranth (<i>Amaranthus</i> sp.)-----	1
Dichromena (<i>Dichromena ciliata</i>)-----	1	Purslane (<i>Portulaca oleracea</i>)-----	1
Corn (<i>Zea mays</i>)-----	13	Aji (<i>Capsicum</i> sp.)-----	1
Nut rush (<i>Scleria</i> sp.)-----	1	Concombre (<i>Cucumis</i> sp.)-----	1

Summary.—Though the blackbird eats fewer mole crickets than is popularly believed, it consumes such large numbers of weevils, directly injurious to cane and other crops, that it should be classed in the foremost rank of beneficial species. Nearly one-fifth of its food is composed of Orthoptera, and many injurious bugs are destroyed. May beetles and white grubs are eaten voraciously and cutworms are favorites. Two of the birds examined had eaten cattle ticks and the birds were observed searching the cattle for them. Considerable numbers of lizards and amphibians are eaten, and these with the corn consumed form the injurious elements in the food. Most of the grain taken was secured in July, and at least one-third of it was waste grain. However, should the blackbirds gather in large flocks to feed on grain it may be necessary to destroy some of them in order to drive others out. It should be ascertained first that they are doing damage, for they frequent cornfields, as they do the cane, for the shade offered from the heat of the sun. No instance of extensive damage to grain came to my notice, depredations being confined to a few ears, a toll

justified by the services of the birds in destroying harmful pests which would do much more injury if unchecked. In general the blackbird is a beneficial bird and the protection accorded it is well placed.

GLOSSY COWBIRD. *Molothrus atronitens* Cabanis.
TORDO.

According to Newton (1860, p. 308), a glossy cowbird (given as *M. sericeus*) was taken on Vieques Island by Mr. Riise. It can be regarded only as an accidental visitant.

PORTO RICAN TANAGER. *Nesospingus speculiferus* Lawrence.
LLOREN, VERDOSO, VERDEDON DE ESPECULO.

(PLATE X.)

The verdoso was found on the eastern and northern slopes of El Yunque, ranging from the thickets and coffee plantations at an altitude of 700 feet to the dense, dimly lighted forests at the summit of the mountain; and was also common about Maricao, this being the first record for the western end of the island. Until the present time but little has been known of this handsome bird. Although the type is marked as taken by Gundlach, he says (1878, p. 190) that it must have been given him by Blanco in 1868, as he had no recollection of it. Dr. C. W. Richmond collected eight specimens on El Yunque in 1900, but the bird was apparently unknown to other collectors. In the present investigations a fine series of skins was taken and data on habits gathered.

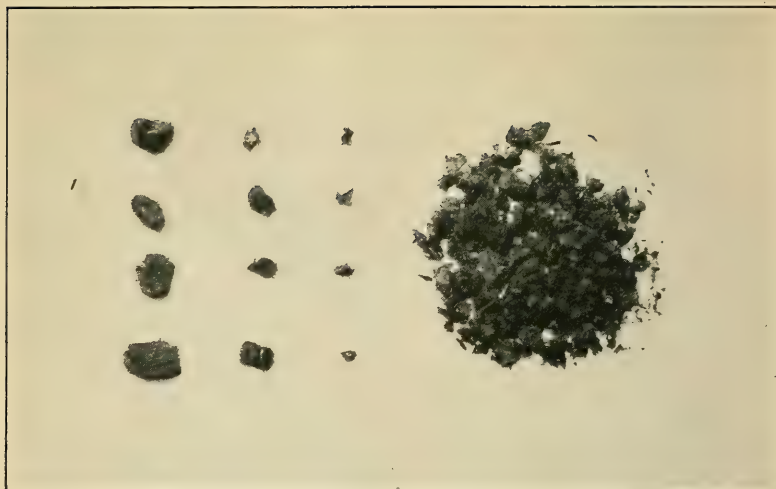
Though in these regions these tanagers were fairly common, they were not easy to secure. In passing along the trails one or two would be heard calling at a distance, or one would appear suddenly in the bushes near by, scolding vigorously, but when silent they were very hard to find. The ordinary call note is a sharp *chewp chewp*, repeated vigorously, while the bird is concealed in a growth of vines or in dense brush. Another note heard less often is a robin-like *tsweep tsweep*. The few natives acquainted with them know them as "the crying birds," from their loud notes, but many living near their haunts knew nothing of them. In March, on El Yunque, they were spread out during the daytime through the brush, many being breeding birds, though occasionally flocks of a dozen or so would appear. At night, however, they gathered in bands to roost. Above the Hacienda Catalina they used three or four royal palms growing near the summit of a ridge. There would be no sign of them until nearly dark, and then suddenly the thickets and patches of gonduros (*Cajanus cajan*) would be alive with the birds coming up the slopes, calling and scolding. From here they flew into the palms, and after much chattering and fighting were settled for the night. Near Maricao, in June, they were breeding, and no flocks were seen. Here they frequented coffee plantations almost exclusively, working actively through the trees above the coffee, fluttering through the twigs, and examining leaves and under sides of limbs, occasionally breaking out with their loud, scolding notes. Several times they were heard singing a sweet warbling song, with many running trills. The flight is strong and undulating, but the birds seldom fly long distances, preferring to hide in the brush. No nests were seen, though the birds were breeding. This tanager will be found perhaps in other scattered localities along the central mountain range of the island. A bird seen near the summit of Mount Pelado above Cayey in January may have been this species.

Food.—In 37 stomachs collected in March on El Yunque and in May and June near Maricao animal food constitutes 59.87 per cent and vegetable 40.13 per cent. In considering the animal matter 8.4 per cent of the total is composed of Orthoptera. One day on El Yunque one of these tanagers picked up a large



B2133-55

PORTO RICAN BLACKBIRD, OR MOZAMBIQUE (*HOLOQUISCALUS BRACHYPTERUS*).



B604M

FIG. 1.—REMAINS OF CATTLE TICKS (*MARGAROPUS ANNULATUS*).

Twelve cattle ticks, besides other miscellaneous food, were found in the stomach of one bird.

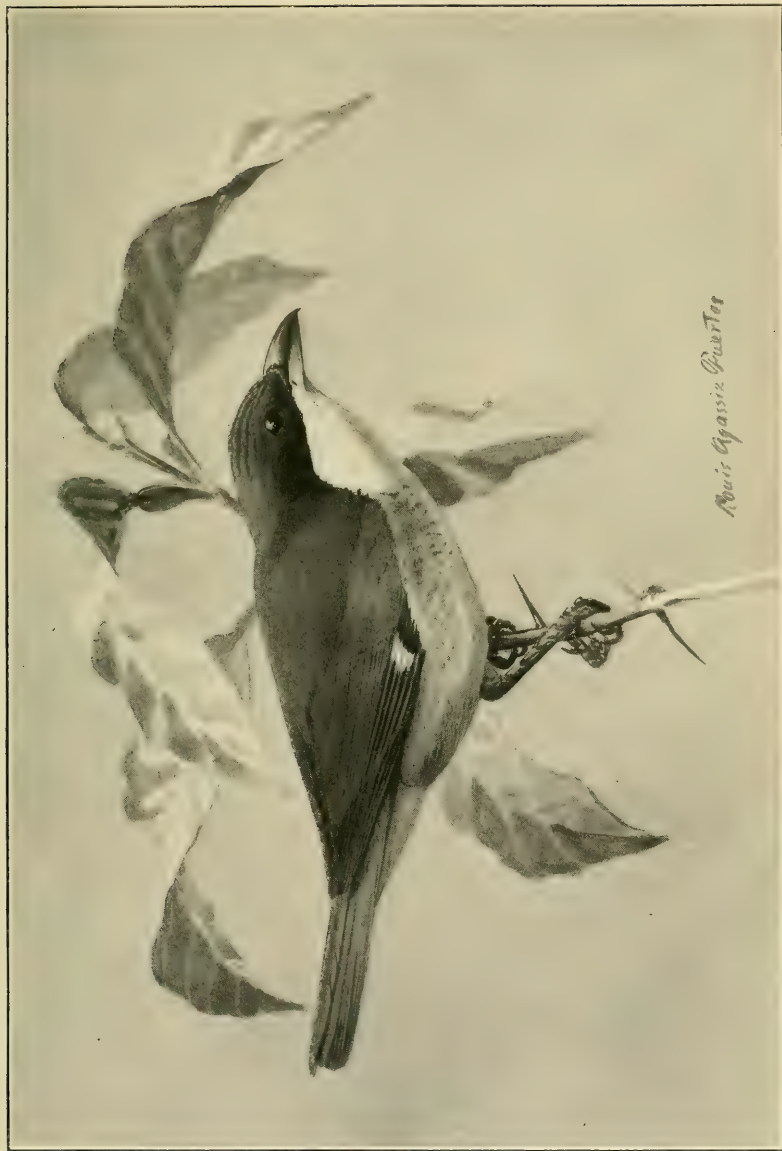


B601M

FIG. 2.—REMAINS OF CANE ROOT-BORING WEEVILS (*DIAPREPES SPENGLERI*).

Snouts of 11 cane root-boring weevils were found in another stomach, in addition to other miscellaneous food.

STOMACH CONTENTS OF PORTO RICAN BLACKBIRD, OR MOZAMBIQUE (*HOLOQUISCALUS BRACHYPTERUS*).



B2135-57

PORTO RICAN TANAGER, OR VERDOSO (*NESOSPINGUS SPECULIFERUS*).

green grasshopper in a trail ahead of me and proceeded to break it up on a limb and eat it as I watched. The coffee leaf-weevil (*Lachnopus* sp.), found in 17 stomachs, constituted 8.5 per cent, while other weevils (0.21 per cent) and various beetles (0.35 per cent) were eaten to some extent. Bug remains in three instances amount to 1.26 per cent.

Moths in 2 stomachs and caterpillars in 21 formed a large bulk (30.94 per cent), more than half the animal food. Remains of Hymenoptera, largely fragments of ants, come to 1.72 per cent, and spiders in six instances constitute 1.49 per cent. Snails (0.72 per cent) were eaten twice, and vertebrate matter (tree toads and a small lizard) comes to 6.12 per cent. Miscellaneous matter figures as 0.61 per cent.

A list of identified material follows:

HEMIPTERA.		VERTEBRATA.	
<i>Lecanium</i> sp-----	1	<i>Eleutherodactylus</i> sp-----	2
COLEOPTERA.		<i>Anolis</i> sp-----	1
<i>Cryptocephalus</i> sp-----	1		
<i>Europs apicalis</i> -----	1		
<i>Lachnopus</i> sp-----	17		

Vegetable food.—The larger portion of the vegetable food consumed by this bird may be classed as wild fruits (25.7 per cent). Berries of various rubiaceous plants were represented most commonly, many being unidentified. Although no sand was eaten to aid digestion, a number of stomachs contained grass seeds and other species with little or no pulpy exterior, which amount to 8.27 per cent, while miscellaneous matter classed as rubbish comes to 6.16 per cent.

The following were identified:

<i>Paspalum</i> (<i>Paspalum millegrana</i>)----	4	<i>Camacey</i> (<i>Miconia prasina</i>)-----	3
<i>Paspalum</i> (<i>Paspalum</i> sp.)-----	2	<i>Adelia</i> (<i>Adelia</i> sp.)-----	1
Panic grass (<i>Panicum</i> sp.)-----	2	<i>Capitana</i> (<i>Phoradendron latifolium</i>)--	1
<i>Palmo</i> (<i>Acrista</i> sp.)-----	3	<i>Sapalo</i> (<i>Palicourea crocea</i>)-----	3
Wild fig (<i>Ficus</i> sp.)-----	2	<i>Rabo de raton</i> (<i>Gonzalaguinia spi-</i>	
<i>Camacey</i> (<i>Miconia</i> sp.)-----	1	<i>cata</i>)-----	2

Summary.—The verdoso is almost entirely a beneficial species, and one of considerable value in the coffee plantations which it frequents. Nearly two-thirds of the animal food is made up of weevils and caterpillars, all serious pests, and the only evil chargeable to the bird is the destruction of a small number of spiders and also of a few lizards and batrachians. Its vegetable food has no value whatever.

The species seems confined to the immediate vicinity of considerable bodies of natural forest, and as at present it has seemingly few enemies, it will perhaps not spread to any extent under protection. In any event, the bird should be encouraged.

PORTO RICAN SPINDALIS. *Spindalis portoricensis* (Bryant).

REINA MORA, TOMATE, LLOROSA, REINONA, LLORONA.

The spindalis is common in Porto Rico, but does not occur in the smaller islands. It is found over the entire island, but comparatively few are encountered in the lowlands, it being most abundant in the hills and mountains. It frequents the patches of second-growth forest, the borders of coffee plantations, hedges, and occasionally citrus groves. The birds are unsuspicious when they alight near one, and peer out of the leaves curiously, but at a distance it is

useless to follow them, as they take alarm instantly. Where food is abundant they are found in flocks in sheltered spots out of the wind. The flight is strong and undulating, the birds sweeping along in graceful curves, alighting for a minute or two, and then passing on, so that in feeding they cover considerable ground. The call note is a faint *tseet*, while the males have a low chattering note. This species has apparently no song. The breeding season extends from the end of January to the middle of June, and occasional pairs breed during the rest of the year. The young are very common during June and July.

The food of the *spindalis* is almost entirely vegetable, and the bird is, without doubt, the greatest disseminator of seeds in the island. Roving in habit, it covers considerable territory, appearing wherever there is food to satisfy its voracious appetite and then passing on. That it does not always confine its attacks to fruit and seeds appears from the fact that, on at least two occasions, it was seen stripping climbing vines (*Ipomea* sp.) of their tender green leaves and eating them. At Rio Piedras the 1st of January two came into a guanabano tree (*Anona muricata*), and in less than half an hour had almost entirely consumed two of the fruits, though the skin was rough and prickly and they were 10 inches long and 5 in diameter. On January 24, near Cayey, a male was seen in the act of opening a ripe wild orange (*china*) and eating the pulp and juice. On half a dozen wild trees near here 30 oranges had been attacked in the same way. The bird occurs in cultivated groves, but was not seen to do any damage. Its work is unmistakable, as it tears a large opening in the fruit from which to extract the pulp, choosing only the ripest fruit.

These birds are frequently infested with a species of parasitic grub, which, however, in most cases does not appear to affect their vitality seriously. The parasites are found usually on the breast just under the skin, though sometimes they occur on the abdomen and underside of the wings. One bird had about 30 of the grubs, but this was exceptional, 2 or 3 being the usual number. The birds were observed in the field eating the following fruits and berries, besides those that have been mentioned: *Pomarosa* (*Jambosa jambos*), *camacey* (*Miconia racemosa*), *palo de perico* (*Cordia corymbosa*), *palo moro* (*Psychotria brachiata*), a wild fig (*Ficus lævigata*), and a *parcha* (*Passiflora seaflora*).

Food.—Animal matter occurred in only 2 of the 96 stomachs of the *spindalis* examined and in each case consisted of fragments of a coffee leaf-weevil (*Lachnopus* sp.). The other stomachs were filled entirely with seeds and bits of the skin of the various wild fruits and berries in season at the time the birds were collected. No sand or gravel was found, and evidently the seeds pass through the large alimentary canal after the soft matter has been removed, or if the seeds are soft they are completely digested. None of the fruits or berries enumerated below has any economic value nor is the dissemination of their seeds of any importance. These birds are the great seed-distributing agencies of the island and to them are largely due the growths of shrubs which cover waste lands, especially in the interior.

Where these birds are found doing serious damage they may properly be destroyed, but damage by them is believed to be rare. Cultivated oranges for the market are picked and shipped before they are ripe enough to be attacked, so that the depredations of the *spindalis* are confined entirely to wild fruit. Very little is destroyed, considering the large quantities of *chinas* growing in a wild state. No trace of coffee berries was found in any of the stomachs. This species may be regarded as harmless and of no economic importance. Its beauty should insure its protection unless it is actually found destroying valuable fruit.

A list of identified wild fruits and berries found in stomachs follows:

Wild fig (<i>Ficus</i> sp.)-----	21	Storax (<i>Styrax</i> sp.)-----	1
Amaranth (<i>Amaranthus</i> sp.)-----	2	Nightshade (<i>Solanum</i> sp.)-----	7
Fresa (<i>Rubus</i> sp.)-----	4	Moral (<i>Cordia</i> sp.)-----	2
Icaco (<i>Chrysobalanus pellocharpa</i>)-----	1	Moral (<i>Cordia nitida</i>)-----	1
Spurge (<i>Chæmesyce</i> sp.)-----	1	Moral (<i>Cordia corymbosa</i>)-----	2
Rhacoma (<i>Rhacoma crossopetalum</i>)--	1	Sapalo (<i>Palicourea riparia</i>)-----	2
Gia (<i>Casearia</i> sp.)-----	1	Roble guayo (<i>Bourreria</i> sp.)-----	1
Camacey (<i>Miconia</i> sp.)-----	4	Tantillo (<i>Randia aculeata</i>)-----	1
Camacey (<i>Miconia prasina</i>)-----	16	Palo moro (<i>Psychotria brachiata</i>)----	1
Murta (<i>Eugenia</i> sp.)-----	1	Pendulo (<i>Citharexylum fruticosum</i>)--	3

PORTO RICAN EUPHONIA. *Tanagra sclateri* (Sundevall).

CANARIO DEL PAIS, JILGUERO, JILGUERO DEL PAIS, CANARIO CRIOLLO.

The euphonia is a tolerably common resident in Porto Rico, but is found only in the hills and not in the coastal plain. It associates in pairs or small flocks and frequents forests and coffee plantations. In the tree tops these little tanagers are rather active, hopping quickly about, and calling *wheur* and a sharp *chit-it*. These notes are rather ventriloquial, but when heard the bird may soon be discovered in the nearest clumps of capitana (*Phoradendron* sp.), the seeds of which form its food. Certain growths with an abundance of ripe berries are visited time after time. The birds usually keep in the thickest parts of the clumps and are rather hard to distinguish from honey creepers. They are at times rather shy, and then fly for considerable distances with a bounding flight.

These birds were in pairs in January and were nesting by the last of February. Young birds were taken May 17 near Yauco, and were common until the first week in July. By August 10 many adults had completed the molt. The males have a low song consisting of the rapid repetition of a single metallic phrase, preceded by louder explosive notes, with twittering interpolations. For this and their bright colors they are prized greatly as cage birds, and about Ponce and Juana Diaz bird catching is a regular occupation with the boys, and the birds are offered in the markets for 5 and 10 cents apiece. In catching them, a bird, usually a female, is shut up in a wicker cage, and a convenient perch or the top of the cage smeared with bird lime. The cage is then placed in a bush, and the captive whistles loudly, calling down the others; or the bird catcher holds the cage in his hand, up toward the trees, where the free birds hop about excitedly calling and whistling loudly. The crate is then moved rapidly back and forth or carried away, the boy running quickly, when the notes of the captive, as it jostles about inside, prove too much for the others, and they fly down. Once they alight, their fate is sealed, and in a few minutes they are inside the cage, themselves captive. In captivity the food is almost entirely ripe bananas and the birds appear to thrive on this diet.

Food.—Fifty-one stomachs of this tanager were examined and in them nothing but the seeds of mistletoe, known as capitana, was found, from 2 to 20 occurring in each stomach. These seeds are small, coated with a thick, transparent, viscous fluid, and are inclosed in an outer envelope. In feeding the berry is broken and the inner portion swallowed, the outer covering being discarded. In dissecting the tanagers the seeds and viscous matter found in the lower part of the intestines were in the same condition apparently as those which remained in the throat, though the nutritive matter had been removed by digestion (Wetmore 1914a). The birds, then, act as distributors of their favorite food, the gelatinous strings supporting the seeds after passing through the alimentary canal catching and lodging on the limbs of the trees and producing new plants. It was noticeable that the mistletoe was very abundant in the dry region of the south coast, as the seeds here were less liable to be washed to the ground before the

heat could dry them and fasten them to the limbs than they were in regions of copious rainfall. Though mistletoe is considered injurious where it is abundant enough to kill the trees so unfortunate as to act as hosts, no complaint was made of it in Porto Rico nor could any damage be attributed to it. It grew commonly in trees serving as shade for the coffee, but no attempt was made to cut it out or keep it down. Infested trees were apparently healthy. The birds are very active and at times I was led to believe that they were capturing insects, but no trace of such food was found in the stomachs examined.

Under present conditions the euphonia has no economic importance and is harmless. It is much prized as a cage bird on the south side of the island and many are trapped. There is no need of restricting this practice when carried on humanely, as the birds, although hunted for this purpose for many years, hold their own. Furthermore, it may be said that these little tanagers thrive and appear happy in captivity, becoming tame and confiding, and bringing enjoyment to many.

Mistletoe, or capitana, seeds of the following species were identified in the stomachs examined:

<i>Phoradendron quadrangulare</i> -----	9	<i>Phoradendron chrysocarpum</i> -----	29
<i>Phoradendron latifolium</i> -----	18	<i>Phoradendron sp.</i> -----	1

PORTO RICAN GROSBEAK. *Loxia portoricensis* (Daudin).

GALLITO, CHURRI, CAPITAN, COME GANDUL.

The grosbeak is a common resident in Porto Rico, occurring along the coast only when there is dense brush, but found through the hills inland. It is seemingly absent or very rare in the eastern third of the island. The birds are shy and are observed often in coffee plantations feeding on the ground. Only occasionally, in little-frequented localities, do they feed in the open. The flight is quick and tilting, and the birds often dodge across from one patch of cover to the next. The males fly into the tops of trees, and, keeping concealed in the leaves, sing a loud cardinal-like song. But for the number heard singing, one would consider them rare, so well do they keep hidden. This is one of the few birds of Porto Rico that sing constantly, so that its song is all the more welcome. The ordinary call note is a low *tsweet*. These birds nest rather irregularly throughout the year, the main nesting period, however, being from February to the last of June. One nest was seen near Salinas on a horizontal limb about 30 feet from the ground. One found June 26, near Lares, was in the top of an inclined coffee tree, about 5 feet from the ground, and though it was large and bulky it was almost entirely concealed. The foundation was of dried banana leaves, and above these sticks, grass, and weed stems were built up, forming a deep cup, lined with grass and rootlets. This nest contained three greenish eggs, spotted and blotched with brown. The young of this species pair as soon as full grown and often before they are in fully adult plumage. The young are most abundant in July and August. The adults are molting then and have almost ceased to sing.

At Lares it was believed that this bird was responsible for much of the damage done to the coffee crop in stripping the berries of the sweet outer pulp, but this I failed to substantiate by actual observation. These birds were sometimes seen scratching in the leaves in dense shrubbery for food. It was surprising to see how well their black color protected them in the dense shadows; only when in motion could the form of the birds be made out, even though close by. They were observed eating the fruit of the following: Icaco (*Chrysobalanus* sp.), manzanillo (*Hippomane manchinella*), pomarosa (*Jambosa jambos*), and sapalo (*Palicourea riparia*).

Food.—The stomachs of 26 of these birds were examined, collected every month from December to August except March. The animal content comprises 29.89 per cent and the vegetable 70.11 per cent. Though animal food was found in every stomach, the quantity was small in some cases, the main dependence for sustenance being upon vegetable matter.

Orthopterous eggs (1.17 per cent) were found in two stomachs taken in December and January. Scarred-snout beetles came to 9.57 per cent, and in three cases were the cane root-boring weevil (*Diaprepes spengleri*) and in five consisted of fragments of coffee leaf-weevils (*Lachnopus* sp.). Miscellaneous weevil remains in eight instances came to 4.57 per cent. With the powerful bill of this grosbeak the insects eaten were ground up into very small fragments so that they were hard to recognize. Fragments of other beetles (10.42 per cent) were found in 12 stomachs, and among them a buprestid (*Acmaeodera* sp.) and a *Cryptocephalus* were identified. Caterpillars (3.07 per cent) were eaten twice. Spiders, found only once, amount to 0.16 per cent. Miscellaneous animal matter, including bits of snail shell, a neuropteran, and a scale insect (*Lecanium* sp.), constitute 0.93 per cent.

Though a few grass seeds are eaten, most of the seeds found in these stomachs are those of wild berries and small fruits, none of any value to man. As much gravel is eaten, the seeds in most cases are ground up and digested, as well as the pulp surrounding them. These stomachs were examined carefully for remains of coffee berries, but no trace of them was found, and from the data available the bird is to be considered beneficial. Though animal food forms slightly less than one-third of the bulk, it is composed almost entirely of injurious insects of considerable importance to agriculture. It may be that this grosbeak feeds at times on coffee or small garden legumes, but few complaints were heard, so that the habit, if practiced, seems to be infrequent.

A list of identified seeds follows:

Paspalum (<i>Paspalum</i> sp.)-----	5	Espino (<i>Xanthoxylum</i> sp.)-----	3
Paspalum (<i>Paspalum millegrana</i>)----	2	Camacey (<i>Miconia</i> sp.)-----	5
Fimbristylis (<i>Fimbristylis</i> sp.)-----	3	Aji (<i>Capsicum</i> sp.)-----	5
Whitetop (<i>Dichromena ciliata</i>)-----	2	Moral (<i>Cordia</i> sp.)-----	3
Star grass (<i>Hypoxis</i> sp.)-----	3	Palo moro (<i>Psychotria brachiata</i>)---	1
Vetch (<i>Vicia</i> sp.)-----	1		

CARIB GRASSQUIT. *Tiaris bicolor omissa* (Jardine).

CHAMORRO, GORRION, CHAMORRO BICOLOR.

The Carib grassquit is an abundant resident in Porto Rico, especially so on the dry south coast. Except at Mameyes and Aibonito, it greatly outnumbered the other species of grassquit. These birds occur wherever there is any cover for them in the cane fields, the maya hedges, thickets, coffee plantations, or second-growth forest. They are tame, unsuspicious little birds, that are found in pairs and sometimes in small flocks. In riding through the cane fields at dusk they were continually fluttering along ahead, so that the cane was full of their rustlings. They were found often working through the trees in various localities, searching through the limbs exactly like honey creepers, and there were so many in the open fields that it was surprising to find them at home in the dense second growth of the forest.

The breeding season appears to extend well through the year, fully fledged young being observed from January to June, and breeding birds were taken in every month in which I collected. Loose flocks, mainly young birds, were encountered all through the year while the adults were in pairs and nesting. Nests were located in maya hedges, or bushes, only a foot or so from the ground, and were always concealed. One found in a coffee plantation near

Yauco May 21 was in the midst of a thick bush about 3 feet from the ground and was made of grass and weed stalks, arched over, with a rough opening at one side. The cup within that contained the eggs was made of very soft, fine grasses, and the eggs were four in number, whitish, heavily marked with cinnamon, and lined somewhat with black.

The males sang all day long from a post, weed, telephone wire, or other open perch, a harsh emphatic little song that reminded me of a dickcissel. In flying they frequently changed to a slow direct flight, with trembling wings, and head thrown back, and sang until another perch was reached. The call note is a low *tseet*.

Food.—Seventy-two stomachs of this small finch were examined, collected in the months from December to September, inclusive, and in these animal food was found in five birds only. The species is almost entirely granivorous in its diet, the animal food coming to a very small percentage of the bulk. Two stomachs contained very slight remains, one of a small homopteran and the other of a spider. One had eaten 11 small caterpillars and 2 roaches, another 4 leaf hoppers, and a third a small caterpillar and a spider.

Seeds of all kinds of grasses and sedge are eaten eagerly and ground up in the muscular gizzard with sand taken for that purpose. They are usually swallowed entire, but occasionally were first neatly hulled. Some of these, as the crab grass (*Syntherisma sanguinalis*), are noxious species abundant in cultivated fields. Other weed seeds of importance as pests also are consumed, as the purslane (*Portulaca oleracea*) and pigweed (*Amaranthus* sp.). Though the bird is accused of eating tobacco seeds left in the fields for seed, no trace of them was found and a bird shot in such a field near Comerio had taken only grass seeds.

This grassquit is entirely harmless and does some good in destroying the seeds of noxious weeds and a few harmful insects, so that it is worthy of a place on the protected list.

A list of seeds identified in these stomachs follows:

Paspalum (<i>Paspalum millegrama</i>)-----	24	Fimbristylis (<i>Fimbristylis</i> sp.)-----	5
Paspalum (<i>Paspalum</i> sp.)-----	1	Sedge (<i>Carex</i> sp.)-----	3
Crab grass (<i>Syntherisma sanguinalis</i>)-----	16	Star grass (<i>Hypoxis</i> sp.)-----	18
Panic grass (<i>Panicum</i> sp.)-----	7	Amaranth (<i>Achyranthes indica</i>)-----	1
Malojillo (<i>Panicum fasciculatum</i>)-----	20	Verdolaguilla (<i>Talinum paniculatum</i>)-----	1
Smut grass (<i>Sporobolus indicus</i>)-----	8	Purslane (<i>Portulaca oleracea</i>)-----	10
Ichnanthus (<i>Ichnanthus pallens</i>)-----	5	Amaranth (<i>Amaranthus</i> sp.)-----	12
Chloris (<i>Chloris radiata</i>)-----	2	Vinagrillo (<i>Oxalis</i> sp.)-----	1
Egyptian grass (<i>Dactyloctenium aegyptium</i>)-----	10	Espino (<i>Xanthoxylum</i> sp.)-----	1
		Nightshade (<i>Solanum</i> sp.)-----	1

BRYANT'S GRASSQUIT. *Tiaris olivacea bryanti* (Ridgway).

GOBBION, CHAMORRO, CHAMORRO BELLO.

Bryant's grassquit is a common resident on Porto Rico and Vieques, but rare on Culebra Island. This species is found entirely in the open, in pastures and cultivated fields, following the maya hedges or scanty growths of bushes. It never goes into the dense thickets, as the other grassquit (*T. b. omissa*) does. Small marshes covered with high grass are favorite localities and in brushy pastures, where the grass is long, the birds are common. They occur all through the year in small flocks, sometimes merely a family group, or again 15 or 20 individuals together. When flushed they fly with an undulating flight to the nearest maya hedge or thicket, and then work rapidly away, or if not further disturbed drop down again to the ground and continue feeding. In the cane fields they retreat before the men advancing in cutting the crop, and

concentrate in pastures and hedges, ready to scatter again over the fields when the new crop is large enough to shelter them. Gundlach (1878, p. 204) says that in his time they came about the crude sugar mills then in operation to eat the sugar as it was manufactured.

The males sing all day long from some elevated perch an insectlike trill which can not be heard at any distance, and the ordinary call note is a faint *tseep*.

The breeding season apparently extends through the entire year. The greater number of the birds nest low down, usually in the grass on the edge of a ditch or depression or in grassy fields. The nest is a ball made of fine grasses, with an entrance in one side. One found near the Hacienda Catalina March 4 contained three eggs, white with a greenish tinge, spotted with cinnamon brown, the spots forming a slight wreath about the large end of the egg. Young birds were noted through the entire year.

Food.—Of 65 birds examined only 1 had eaten insect matter, and this had picked up 8 spiders and a leaf hopper (*Tettigonia* sp.). The great bulk of the food consists of grass seeds, some of species regarded as weeds, as the crab grass (*Syntherisma sanguinalis*), seeds of which were found in 23 stomachs. All the common species of grasses are represented, and besides these a few seeds of a sedge (*Fimbristylis* sp.) and star grass (*Hypoxis* sp.) were found. This grassquit is entirely harmless, and though practically no insects are taken it destroys many seeds of injurious weeds, so that it should be protected.

A list of seeds identified in these stomachs follows:

Paspalum (<i>Paspalum millegrama</i>)-----	27	Smut grass (<i>Sporobolus indicus</i>)-----	3
Paspalum (<i>Paspalum</i> sp.)-----	9	Ichnanthus (<i>Ichnanthus pallens</i>)-----	16
Crab grass (<i>Syntherisma sanguinalis</i>)--	23	Chloris (<i>Chloris radiata</i>)-----	4
Malojillo (<i>Panicum fasciculatum</i>)-----	8	Fimbristylis (<i>Fimbristylis</i> sp.)-----	9
Panic grass (<i>Panicum</i> sp.)-----	8	Star grass (<i>Hypoxis</i> sp.)-----	14

SANTO DOMINGAN GRASSHOPPER SPARROW. *Coturniculus savannarum intricatus* Hartert.

GORRION, CHAMORRO.

The grasshopper sparrow is resident in Porto Rico, but now found apparently in only a few localities. A colony of 35 or more was located near Yabucoa May 10. It was common north of Cabo Rojo August 24 to 31, and was frequently seen along the Bayamon River near Bayamon July 20 to 25. This species would seem, then, to occur only in the lowlands, though there is in the United States National Museum one specimen from Caguas. Bowditch (1902-3, p. 13) records it as fairly common near San Juan, Aguadilla, and Mayagüez in the period from 1899 to 1901. A series of birds collected belong to this subspecies (described by Hartert from El Valle, Santo Domingo). They are found only in open pastures where the grass grows high enough to afford shelter, or on waste land, as the gravel bars along the Bayamon River. As more and more of these areas are broken up and cultivated the birds will become rarer.

This is a very inconspicuous species and one easily overlooked. In passing through their haunts they are seen merely to skulk to one side in the grass or fly up just behind one, and after a short, rather weak flight drop back again into cover. On the ground they creep along through the grass, or hop when it is more open, stretching up their heads and flirting their tails nervously. The song of the males is a weak effort that may be represented by the syllables *tsick tsee—ee—ee—ee*, the first syllable sharp and quick and the last insectlike. The song is very ventriloquial, the first part seeming to come from one side and last from another. The birds sing from a weed top a foot or more above the ground, and by inspecting these closely the sparrows may be located after a few

minutes. They sing occasionally even as late as August, but not so much as earlier in the summer.

They nest from May to August (Bowdish records a nest at Aguadilla June 16, 1900), and it would appear that two broods are raised. Their ground-haunting habits and nests lay them open to attacks of the mongoose and doubtless many are destroyed. The last of July, near Bayamon, one immature bird in fresh fall plumage was taken, but most of the young were then in juvenile dress. The adults were very worn at that time, some of them having the rectrices much abraded or even broken, but they were not molting. Here another song was heard, a series of low twittering notes, even harder to locate than the other, while the call note was a scolding *tsip*. The young birds, now shifting for themselves, were common along the gravel bars in the stream, sometimes perching, two or three together, in low weeds, and acting more curious than afraid.

Food.—Thirty-two stomachs of the grasshopper sparrow were at hand for examination, collected in May, July, and August. Animal food forms 65.9 per cent and vegetable 34.1 per cent, these figures corresponding very closely to what is known of the food of allied subspecies in the north. Orthoptera, Lepidoptera, and Coleoptera form the bulk of the animal food and seeds of grass and other plants compose the vegetable portion.

Animal food.—Two birds had eaten nymphs of the mole cricket (0.25 per cent), and crickets seem to be favorite food, as they were found in seven stomachs, and at Bayamon a female was feeding a large cricket (*Anurogryllus muticus*) to her young. Grasshoppers were noticed in four stomachs and Orthoptera as a whole occurred in 17 birds, constituting 24.82 per cent of the total. Lantern flies were eaten seven times and come to 1.28 per cent and other Homoptera, all small species, to 1.48 per cent. Stinkbugs in four instances and a few fragments of other bugs constitute 3.75 per cent. Leaf beetles (5.3 per cent) were favorites with the grasshopper sparrow and many were eaten. A striped flea-beetle (*Systema basalis*), a species destructive to all small garden crops and vegetables, was found in 12 stomachs. A tortoise beetle was taken twice, a bean leaf-beetle (*Cerotoma denticornis*) once, and a *Diabrotica* once. Scarred-snout beetles (0.87 per cent) were eaten four times and include one cane root-borer (*Diaprepes spengleri*). Curculios amount to 2.25 per cent and miscellaneous weevil remains to 0.25 per cent. Small fragments of other Coleoptera total 0.97 per cent. One carabid was eaten. All of these hard-shelled insects were very finely ground in the stomachs of this bird.

Remains of Hymenoptera (1.33 per cent) were in nine instances those of ants, and in two the fragments of small parasitic species. Twenty-one birds had eaten caterpillars, and one a moth, all coming to 14.8 per cent. Spider remains in eight stomachs amount to 7.75 per cent, and other animal matter, bits of a snail, insect eggs, and unidentified material, come to 0.8 per cent.

A list of identified animal matter follows:

ORTHOPTERA.		COLEOPTERA—continued.	
<i>Scapteriscus didactylus</i> -----	2	<i>Systema basalis</i> -----	12
		<i>Coptocycla signifera</i> -----	2
HEMIPTERA.		<i>Platyedra</i> sp -----	2
<i>Ormenis</i> sp -----	2	<i>Diaprepes spengleri</i> -----	1
<i>Corixa</i> sp -----	2	<i>Lachnopus</i> sp -----	1
		<i>Euscepes porcellus</i> -----	1
COLEOPTERA.		HYMENOPTERA.	
<i>Cerotoma denticornis</i> -----	1	<i>Solenopsis geminata</i> -----	2
<i>Diabrotica graminea</i> -----	1	<i>Pheidole subarmata borinquensis</i> -----	1

Vegetable food.—Vegetable matter was found in all but 2 of the stomachs examined, most of it in 20 stomachs collected in July, when it comes to 46.7 per cent. This matter consists entirely of seeds, largely those of grasses, with a few sedges and miscellaneous weed seeds. Some of the species taken are notorious weeds. These are all ground up in the strong stomachs and digested with the aid of sand.

A list of identified seeds is given below:

Paspalum (<i>Paspalum millegrana</i>)----	11	Whitetop (<i>Dichromena ciliata</i>)-----	2
Paspalum (<i>Paspalum</i> sp.)-----	1	Sedge (<i>Carex</i> sp.)-----	1
Crab grass (<i>Syntherisma sanguinalis</i>)--	4	Star grass (<i>Hypoxis</i> sp.)-----	8
Malojillo (<i>Panicum fasciculatum</i>)-----	8	Amaranth (<i>Amaranthus</i> sp.)-----	5
Panic grass (<i>Panicum</i> sp.)-----	3	Purslane (<i>Portulaca oleracea</i>)-----	4
Smut grass (<i>Sporobolus indicus</i>)-----	2	Vetch (<i>Vicia</i> sp.)-----	2
Ichnanthus (<i>Ichnanthus pallens</i>)-----	1	Verdolaguilla (<i>Oxalis</i> sp.)-----	1
Egyptian grass (<i>Dactyloctenium ægypticum</i>)-----	1		

Summary.—No evil can be attributed to the grasshopper sparrow, and it is to be regretted that it is not so abundant as the ever-present grassquits. Orthoptera, including a small number of mole crickets, form one-fourth of the food, and besides large numbers of weevils and caterpillars are eaten. In 32 stomachs only one beneficial beetle and two parasitic chalcids were found, while spiders were eaten in small quantity. The remainder of the animal food was composed entirely of injurious insects of great economic importance. Some of the seeds eaten are those of noxious weeds, and none of any actual value, so that this element in its food also adds to the usefulness of the bird. Though few in number, it is a species of considerable importance to the island.

[**RED SISKIN.** *Spinus cucullatus* (Swainson).]

DOMINIQUE.

Sundevall (1869, p. 597) includes the red siskin in his list as received from Hjalmarson, and on this is based the belief that this siskin has been naturalized in Porto Rico. Gundlach, however (1878a, pp. 174–175), says that Hjalmarson assured him his specimen was a cage bird, so that the siskin has no status as a Porto Rican bird and is included here merely to correct the many statements that it has been found on the island in a wild state.]

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BULLETIN No. 327



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HENRY S. GRAVES, Forester

Washington, D. C.

PROFESSIONAL PAPER

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THE SPRUCE AND BALSAM FIR TREES OF THE ROCKY MOUNTAIN REGION.

By GEORGE B. SUDWORTH, *Dendrologist*.

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SCOPE OF THE BULLETIN.

This bulletin deals with the distinguishing characters, geographic distribution, and forest habits of all of the spruce and balsam-fir trees that grow naturally within the Rocky Mountain region, which roughly includes the desert and mountain territory lying between the Great Plains and the eastern border of the Pacific Slope States. Canadian territory lying directly north of our Rockies and Mexican territory adjacent to our Southwest are included, because the ranges of some of the spruces and firs extend into these regions. The method of treating the subject, sources from which data on the geographic range were obtained, and the origin of other information used in this bulletin are fully discussed by the writer in a recently issued publication on the "Cypress and Juniper Trees of the Rocky Mountain Region."¹ Acknowledgments made there of assistance received apply also in the case of the present bulletin.

¹ Bulletin No. 207, U. S. Department of Agriculture, 1915.

NOTE.—This bulletin will be of service botanically or commercially for the trees described.

The class and family relationship of the spruces and balsam firs to other cone-bearing trees of the Rocky Mountain region is fully explained in the above-mentioned publication, to which the reader is referred for this general information.

Keys are provided on pp. 42 and 43 for the identification of genera and species.

GENERIC CHARACTERISTICS OF SPRUCES.¹

The spruces are evergreen trees with sharp-pointed, pyramid-shaped crowns and conspicuously straight, tapering trunks. The branches grow from the trunks in regularly distant circles or whorls. Their stiff, acute, often very keenly pointed, single leaves have a characteristic spiral arrangement on the twigs and branches which they clothe on all sides. The leaves of each season's growth adhere to the branches for from about 7 to 10 years. When the leaves die and fall from the branches they leave a basal portion which gives the branches a rough appearance.² All but two of the North American spruces have more or less distinctly 4-angled leaves, all sides of which are provided with minute stomata or pores. Leaves of the other two species are flat, being very indistinctly 4-angled, or flat triangular in cross section, and with minute pores only on the upper surface. In cross section the leaves of spruces usually show one or two resin ducts situated very near the lower surface; in some cases the leaves have no resin ducts. The winter buds of the spruces are made up of overlapping scales and, unlike those of the fir trees, have no resinous covering.

Male and female flowers of spruces are borne on the same tree and on twigs of the previous year's growth. The male or pollen-bearing flowers are upright or drooping, yellow, bright purple, or rose-red, long or short, cylindrical bodies, about three-fourths inch to 1 inch by one-fourth to one-half inch. The female flowers, which produce cones and seed, are erect, yellowish-green or bright

¹ Considerable confusion still exists, especially among nurserymen, regarding the trees that are properly included in the genus *Picea*, which in 1830 the German botanist Link technically adopted as a generic name for the true spruces as we now know them. It seems probable, but this can not be established, that Pliny first used *Picea* as a classical name for a fir and *Abies* for a spruce tree. Later writers used *Picea* for the spruces and *Abies* for the firs, while in 1719 Tournefort consigned the firs, spruces, and our hemlock to the genus *Abies*. In 1754 Linnaeus went still farther by combining under *Pinus* the firs, spruces, hemlock, and larch. This gave rise to such peculiarly anomalous technical names as "*Pinus abies*" for the Norway spruce, "*Pinus picea*" for the European silver fir, and "*Pinus larix*" for the European larch. As late even as 1836 Endlicher maintained Link's use of *Picea* for the spruces, but made it a subgenus of *Pinus*. From 1837 to 1858, however, such eminent authors as D. Don, Loudon, and Gordon used *Abies* for the spruces and *Picea* for the balsam firs. Notwithstanding the fact that properly all European and American botanists maintain *Picea* as the only legitimate generic name for the spruces and *Abies* for the firs, many European and American nurserymen and horticulturists continue to use *Picea* for the firs and *Abies* for the spruces, some even including the hemlocks (*Tsuga*) in the latter genus.

² See p. 18 for statement regarding the characteristic leaf-scars of firs.

red bodies of similar form, from three-fourths inch to about 1½ inches in length by one-fourth to nearly three-fourths inch in diameter. The cones, matured in one season, are cylindrical or egg-shaped, always pendant or bent downward (Pls. I to V). Most of the spruces bear their cones at the extreme top of the crown; some bear cones on branches of the upper half of the crown. As a rule, the cones are only lightly attached to the twigs, and after shedding their seed, in early or late autumn, they either fall from the trees during the winter or by spring. The cones of a few spruces are firmly attached and remain on the branches for a number of years after their seeds are shed. The scales of spruce cones are thin and without prickles (Pls. I to V), in this respect being unlike the thick, strong cone scales of pines, which often have sharp, strong prickles. Like the cone scales of the pines, however, they are firmly attached to a central woody column, and never fall away until the cone is rotted to pieces. Two seeds (Pl. I, *b*) are borne under each fertile cone scale; no seeds are produced by the usually much-aborted scales at the two ends of the cones. The seeds are light and provided at one end with a thin wing which renders them so buoyant that the wind disseminates them widely. The seed-leaves, the first foliar organs to appear after the seed germinates, are commonly from 5 to about 15, or sometimes only 4 in number (Pl. III, *b*).

The spruces are exceedingly important forest trees, and some are much planted for ornament. They yield superior saw timber, the straight and even grained wood being used for a great many commercial purposes, including paper pulp, for which it is unsurpassed.

Seven species are indigenous to North America, all of which occur abundantly, or exclusively, within the United States. Four species are distributed over the western half of the United States, and three range mainly through northeastern United States and Canada, while two of these extend, almost entirely in Canada, from the Great Lake region into Alaska.

Species of this genus are of ancient origin, representatives of the group having existed from the Middle Cretaceous period to the Recent, while cones of both *Picea canadensis* and *P. mariana*, the white spruce and black spruce of to-day, are abundant in postglacial deposits at Chicago, Ill.¹

BLACK SPRUCE.

Picea mariana (Mill.) B., S., and P.

COMMON NAME AND EARLY HISTORY.

This species has long been known as black spruce, a name probably coined from the tree's most widely used technical name, *Picea nigra*,

¹ The writer is indebted for this statement of the geologic history of *Picea* to Dr. Edward W. Berry, paleontologist, Johns Hopkins University, Baltimore, Md.

doubtless suggested by the dark blue-green foliage, which contrasts strongly with the ashy or glaucous green hue of the white spruce found in the same general region. "Swamp spruce," "bog spruce," and "muskeg spruce," are local names applied to it when found growing in wet, marshy places. Black spruce was doubtless well known to the French and English settlers in eastern Canada and New England at least as early as the seventeenth century, but the first definite account of it was not published until 1755,¹ and then not under a technical name. The black spruce was first technically described and named "*Abies mariana* Miller" in 1768. From 1800 to 1888 it was, however, known to botanists and horticulturists as *Abies nigra* and as *Picea nigra*, its present accepted name, *Picea mariana* (based on *A. mariana*), not being established until 1888.

Several different forms of the black spruce have been named as distinct species (now doubtfully tenable), while about seven named horticultural varieties are distinguished in cultivation.²

DISTINGUISHING CHARACTERISTICS.

Black spruce is mainly an eastern and far northern species, included here because it occurs in the Canadian Rocky Mountain region. There it is from 25 to 40 feet high and from 4 to 8 inches in diameter. In its wider eastern range this tree exceptionally attains a height of from 50 to 75 feet and a diameter of about 1 foot; very occasionally it grows to 100 feet in height and 2 to 3 feet in diameter. The crown is characteristically open and irregular, extending to the ground, except in middle-aged or old trees grown in a dense stand, where the lower half of the trunk is clear of branches. The usually short, slim branches, often distant from each other, commonly droop at their ends, but some forms of the tree have peculiarly stiff branches. A stunted form of this tree growing in wet marshes has tufts of very short branches, only or chiefly, at the top of the stem. The great variation in the habit of the branches and density of the crown appears to be due entirely to differences in habitat, which ranges from wet, boggy marshes to dry uplands.

The foliage is a deep blue-green, with a tinge of whitish, the short leaves (Pl. I) standing out on all sides of the branches. A cross section of the leaves shows two minute resin ducts close to the surface and near the angles of the leaf. The bark of old trees is thin and composed of small ashy-brown scales. The young twigs of a season's growth are usually a pale russet-brown, coated with small hairs of similar color.

¹ Du Hamel, *Traité des arbres et arbustes*, I, 17, 1755.

² See *Nomenclature of Arborescent Flora of U. S.* (Bull. 14, Div. Forestry, U. S. Dept. Agr.), 34, 1897. These "varieties" are distinguished chiefly by slight differences in the shape of the crowns and by the color of the foliage. The variety known in cultivation as "*Picea nigra* Doumetii" is very distinct in its narrowly pyramidal, dense crown.

PICEA CANADENSIS: BRANCH WITH DENSELY CLUSTERED OPEN CONES. (ABOUT ONE-HALF NATURAL SIZE.)





PICEA MARIANA: FOLIAGE.

a, Open cones; b, upper (left) and lower sides of seeds with wings.

The cones (Pl. I, *a*) are ripe by the end of August, when they are pale ashy brown, and within a few weeks afterwards they shed their small winged seeds (Pl. I, *b*). Because of their very stout, firm stems the cones of this spruce remain firmly attached to the branches for very many years, a characteristic which roughly distinguishes this tree from other species of its range. The stems of the cones are curved downward or inward toward the branch. Scales of the open cones are peculiarly stiff and resistant to pressure of the hand, but are easily broken if squeezed together. The seeds (Pl. I, *b*) are a deep chocolate brown. Seed-leaves, usually 6, are about one-half inch long or shorter.

Black spruce wood is usually of a clear, very light yellow color. It is characterized by a thin layer of sapwood and very narrow annual rings of growth. It is heavier than that of any other native spruce, a cubic foot of seasoned wood weighing nearly 33 pounds. The color of wood from different individual trees of this species often varies greatly, so that it is easy to confuse the wood with the pale or yellowish-white wood of the white spruce, with which black spruce wood may be mingled occasionally as lumber. Black spruce is commercially the least important of all the eastern spruces, chiefly on account of the small size of the tree, which in the eastern part of its range is cut mainly for paper pulp.¹

OCCURRENCE² AND HABITS.

Black spruce is essentially a swamp tree, characteristic of cold, wet bogs and margins of lakes (Map No. 1). It grows on clay and heavy glacial drift, and occasionally also on high, well-drained hill soils, where it is much less abundant than in moister sites and is small and stunted. The best growth is found in constantly moist, well-drained alluvial soils, while the tree is most abundant in wet soils. Depth of soil is not essential, owing to shallow root system. The vertical range is imperfectly known at present, but the tree occurs more or less at elevations between about 100 and 3,500 feet. Black spruce forms pure forests over limited or small areas, the largest and best stands occurring in moist, well-drained alluvial bottoms. It also grows in mixed stands associated with tamarack, black cottonwood, balm of Gilead, aspen, willows, and alders.

¹ Considerable quantities of "spruce gum" are collected from injured places in the trunks of black spruce, chiefly, however, in the tree's eastern range, where the white and red spruce also yield a part of this crude product, which is later refined and prepared for market.

² William Aiton states in his "Hortus Kewensis" that black spruce was introduced into England in 1700. According to Elwes and Henry (The Trees of Great Britain and Ireland, VI, 1377, 1912), black spruce planted near Colesborne attained a height of 56 feet and a diameter of about 11 inches in 55 years. Trees planted in Scotland in 1832 were 40 feet high in 1904. The trees planted in moist or wet situations appear to be thrifty, while those set in drier places have proved to be short-lived.

It is very tolerant of shade, being able to recover from suppression up to an advanced age. Dense stands of black spruce produce a heavy crown cover, which frequently shades out tamarack and other intolerant trees. Black spruce is most tolerant on wet soils, which are often covered with dense stands of slow-growing trees, and least tolerant of shade in dry, well-drained situations, where it usually grows in more open stands. Ability to endure dense shade enables the trees to retain their side branches for a relatively long time, those with clear trunks occurring only in the densest stands.

Black spruce is not a prolific seeder, although some seed is usually borne locally each year; abundant seed production occurs only at rather long, irregular intervals. The seed has a moderately high germination and persistent vitality. Germination is best on constantly moist mineral or humus soils, on wet, decayed fallen trees, moss, and moist, decomposed spruce leaf litter. The leaf litter of broadleaf trees is not, as a rule, favorable to germination, because the seedling roots can not penetrate the tough mass of duff. Seedlings require at least moderate shade for their development during the first one or two seasons, while the young plants grow most thriftily in dense shade.

The lower branches of black spruce trees frequently take root when lying in close contact with moist earth or leaf mould, and produce clusters of little trees under the shade of the mother tree.

LONGEVITY.

In general, black spruce is moderately long-lived, trees of average size being from 125 to 200 years old. Trees in wet situations grow very slowly, often only 1 to 2 inches in diameter in 75 or nearly 100 years. Further age determinations are desirable of trees grown in the moister and drier situations.

WHITE SPRUCE.

Picea canadensis (Mill.) B., S., and P.

COMMON NAME AND EARLY HISTORY.

Picea canadensis is most commonly and widely known as white spruce, this name referring to the whitish hue of the foliage. It is also locally known as "cat spruce" and "skunk spruce" because of the polecatlike odor given off by the foliage and young twigs, especially when crushed. White spruce was the first of our spruces to receive published notice, an account of it appearing as early as 1535¹ and again in 1620.² The first of these records refers to trees

¹ "Bref Recit et Succincte Narration de la Navigation faite in m^dxxxv. m^dxxxvi, Parle Capt. Jacques Cartier aus Iles de Canada," 24, 1535.

² John Mason, "A Brief Discourse of the Newfoundland."

seen along the Saguenay River, in southeastern Quebec, Canada, and the second account tells of trees observed in Newfoundland, where the species is abundant. It was technically described and named for the first time as "*Abies canadensis* Miller" in 1768, although the author of this name previously described the tree without naming it in 1731. During the century and a half that white spruce has been known to science no less than 20 different specific and varietal names have been given to various forms of it.¹ Down to 1888 botanists knew it chiefly either as "*Abies alba* Michaux" (published in 1803) and as "*Picea alba* Link" (published in 1831), its present generally accepted name, *Picea canadensis* (based on *Abies canadensis* Mill.), having been established in 1888.

DISTINGUISHING CHARACTERISTICS.

White spruce is only sparingly represented in our Rocky Mountain region, its main range being in northeastern United States and Canada. It varies in height, according to situation, from 15 to 75 feet and in diameter from 12 to 20 inches. The largest trees occur in the East, where the height is from 80 to 100 feet or more and the diameter from 24 to 36 inches. Trees 3 or 4 feet in diameter and over 100 feet high are rather rare. The trunk is straight and clear of branches for one-third to two-thirds of its length, with a somewhat open, irregular, and widely pyramidal crown, the top of which, especially in old trees, may be rounded or flattened; very often, however, the crown is sharply pointed. The branches are long and thick, and commonly curve down and then upward. A striking characteristic of the branches is their numerous small, drooping side branchlets.

Bark of the trunks is thin, rarely over one-half an inch thick, and is early broken into small, thin, pale, ashy-brown scales, the color, however, varying greatly with the density of the stand.

The dense foliage is characteristic in its light blue-green color, which in some individuals has a distinct whitish tinge.¹ The 4-angled leaves (Pl. II) grow from all sides of the twigs, and often stand out loosely; but for the most part they appear to grow on the upper sides of the branches, particularly at and near their ends, the lower leaves being bent upward, so that all appear to be massed on the upper side. A cross section of the leaves shows two minute resin ducts close to the border and near the angles of the leaves. Twigs of a season's growth are dark yellow-brown, and, as a rule, are

¹ White spruce has been cultivated for ornament for many years both in Europe and in this country. Loudon (Arb. et Frut., IV, 2312, 1838) informs us that Bishop Compton introduced it into England in 1700. Some 10 different garden forms have been developed and are now technically named. They are all distinguished from the species chiefly by their smaller size, shape of the crown, or color and habit of foliage and branches. The best marked garden variety is *P. canadensis glauca*, which is a handsome form with pale blue-green foliage closely pressed upon the twigs.

smooth, but twigs of the far northwestern forms of this species are apt to be finely downy. A notable distinguishing character of the foliage and young twigs is the fetid, polecatlike odor they emit, especially when bruised. Foliage a year old or older gives off a much less distinct odor, while the odor of foliage from different trees varies greatly in intensity.

The pendulous cones (Pls. II and III) are borne mostly at the top of the tree, but occasionally a few are produced on the middle and lower crown branches. They reach maturity by the end of one summer, when they may be light grass-green tinged with red or bright rose-red. The small, light, yellow-brown seeds (Pl. III, *a*) are shed in September. After shedding their seeds the cones are a light clay-brown. Being lightly attached to the twigs, they usually fall from the trees during autumn or by the following spring. They vary in length from about 1 inch to nearly $2\frac{1}{2}$ inches, but are usually about $1\frac{3}{4}$ inches long. When open and dry the cone-scales are so thin and flexible that they can be squeezed together without breaking them. The seed-leaves (Pl. III, *b*), which vary in number from 6 to 9, are slender and from one-half to nearly three-fourths of an inch long.

The wood of white spruce is pale yellowish-white, rather soft in texture, straight-grained, and with very narrow growth rings; the thin layer of sapwood is only slightly paler than the heartwood. White spruce wood ranks fourth in weight among native spruces, a cubic foot of seasoned wood weighing $25\frac{1}{4}$ pounds. Commercially the white spruce is one of the two most important timber spruces of northeastern North America.¹ Here it is extensively cut for lumber, which is used in general construction work and for interior finish. Large quantities are also cut for paper pulp. In its western range white spruce is locally used chiefly for lumber in rough construction work.

¹ Stewardson Brown believes there is a second distinct species of white spruce which he found in the Canadian Rockies of Alberta and British Columbia. He describes this tree as growing at low altitudes in wet ground and on river bottoms, where it often occurs to the exclusion of all other trees. Dr. N. L. Britton ("North American Trees," p. 58, 1908) has given this species the common name "Western white spruce" and states that it ranges "from Wyoming and Montana north and westward into British Columbia." Mr. Brown's description of the tree follows:

"This species has been referred by authors to *Picea canadensis* (Mill.), B. S. P., and *P. mariana* (Mill.), B. S. P., to both of which it bears a certain resemblance, but from two months' experience with the tree during the past season in the region from Banff, Alberta, to Field, British Columbia, I am satisfied that it is quite distinct from either, and therefore propose for it the following name:

"*Picea albertiana* sp. nov.—A slender tree, attaining a height of over 15 meters. Twigs and sterigmata smooth and shining or occasionally slightly granular but never glaucous, yellowish brown when young, becoming darker with age; sterigmata strongly reflexed and standing out frequently more than 1 millimeter from the twigs; leaves pale blue or blue green, surrounding the stem and crowded toward the upper side, at the ends of the branches, 1.5 to 2.5 centimeters long, four-sided, with three, four, or sometimes five rows of stomata on each side, incurved, acute, or acuminate with a rigid tip; cones





PICEA CANADENSIS: FOLIAGE AND OPEN CONES.

a, Upper (right) and lower sides of seeds with wings; b, seedling, one month old.

OCCURRENCE AND HABITS.

Picea canadensis occurs on river banks, terraces, dryish margins of swamps and lakes, and on adjacent sides of ridges and hills at elevations of from near sea-level up to about 5,000 feet (Map No. 2). It is most frequent on sandy loam soils with moderate moisture, but grows on very shallow soils from the margins of swamps to the tops of mountains. The largest trees are found in moist, well-drained, finely divided porous soil; situations too dry or too wet produce dwarfed, stunted, slowly grown trees. White spruce forms pure dense forests, often of great extent. It occurs also in mixed stands. Usually it forms extensive pure forests in well-drained soils along rivers and on lower valley slopes. On wet or moist flats it often gives way to black spruce, tamarack, or cottonwoods, and on dry terraces to lodgepole pine. At timber line it is sometimes associated with alpine fir. Dense groves and strips of pure white spruce occur frequently, closely associated with birch, alder, aspen, willows, and black cottonwood.

Picea canadensis is tolerant of considerable shade from the seedling to pole stages of growth. Young trees are able to maintain themselves for many years under rather heavy crown cover and to recover from suppression when given top light, being surpassed in this respect only by the black and red spruces. With top light the trunks of young trees retain their lower side branches persistently, long, clear stems occurring only in very close stands of older growth. Thriving under light shade of poplars and birches, this spruce often replaces these trees after fire or lumbering.

White spruce is a moderately prolific seeder. Considerable seed is produced locally every year, while heavy seed production occurs over parts of its range at more or less regular intervals of from five to eight years. The seed has only a moderately high rate of germination, but persistent vitality. Good germination of the seed occurs

ovate, bright crimson when young, at maturity 2.5 to 3.5 centimeters long and nearly as broad when expanded, early deciduous; scales stiff and rigid, broadly rounded at the apex, entire, broader than long, cinnamon-brown with a chestnut edging and shading to darker chestnut toward the base; bract 2 millimeters or less long, 1 millimeter broad, with a sharply angular, more or less acute erose tip.

"Type: No. 796, S. Brown, Bankhead, Alberta.

"The common spruce of the lower altitudes through the Canadian Rockies in Alberta and British Columbia, differing from *P. canadensis* (Mill.), B. S. P., in the longer, strongly reflected sterigmata, shorter, broader, and darker-colored cones, with broadly rounded scales and minute sharply angled bracts and from *P. mariana* (Mill.), B. S. P., in the lighter-colored smooth twigs with longer sterigmata and light-blue or blue-green leaves, and cones with broader, entire scales with angular-tipped bracts." (Torreya, vol. 7, 125, 126, June, 1907.)

The present author has not seen authentic specimens of this tree on which the above description is based. As nearly as can be judged from descriptions of its characters it appears to be closely related to *Picea canadensis*, particularly in the color and form of the foliage and cones. Dr. Britton's figures (l. c. 45) of a cone shows some of the cone scales, however, to be decidedly different in form from those of *Picea canadensis*.

only on moist, decomposed organic, or mineral soils. Natural reproduction is usually abundant under mature spruce on damp moss over organic soil, and on moss-covered decayed logs and stumps. White spruce reproduces itself poorly on thick leaf-litter of broadleaf trees, because, as in the case of black spruce, the seedlings can not penetrate the tough mass.

LONGEVITY.

White spruce is a long-lived tree, reaching an age of from 250 to 300 years.

ENGELMANN SPRUCE.

Picea engelmanni Engelm.¹

COMMON NAME AND EARLY HISTORY.

Lumbermen and other woodsmen know this tree mostly as "spruce," while some call it "white spruce," probably because of its general resemblance to the true white spruce (*Picea canadensis*), with which they may have become acquainted in the East. It is, however, commonly known to foresters and botanists as Engelmann spruce, a name which it is hoped may be generally adopted both because of its distinctness and the fact also that it commemorates the name of one of the ablest students of western trees.

It seems probable that Lewis and Clark were the first discoverers of this species, while crossing the Bitter Root Mountains in 1805 on the Lolo Trail. Mention is made in their narrative² of a "spruce," which must have been the tree we now know as *Picea engelmanni*. To Dr. C. C. Parry belongs the credit of having first distinguished this tree, in 1862, from the black spruce (*Picea mariana*), for which earlier plant explorers of the Rockies had mistaken it. In that year Dr. Parry found Engelmann spruce on Pikes Peak, Colo., and in 1863 is said to have sent seeds of it to the Botanic Garden of Harvard University, where it was probably cultivated for the first time in this country.³ The first technically established name¹ and description of

¹ Dr. George Engelmann did not name this tree in honor of himself, as might appear from the present form of its technical name. Dr. Parry (Trans. Acad. Sci., St. Louis, II, 122, 1863), recognizing that this tree had been erroneously referred by Engelmann to *Abies nigra* (another distinct species), called it *Abies engelmanni*, which proved to be a nomen nudum. Later Engelmann (loc. cit., 212) cited Parry's name, *A. engelmanni*, and in doing this formed a new name, *Picea engelmanni*, which he credited to Parry. As a matter of fact, Parry did not write *Picea engelmanni*; consequently Engelmann was the first publisher of the name *Picea engelmanni*, but certainly with no intention of naming this tree in honor of himself.

² Hist. of Expedition under Command of Lewis and Clark (ed. Coues), II, 590. Whether the discovery was made on the Montana or Idaho side of the Bitter Roots, which the Lolo Trail crosses, appears to be unknown.

³ According to James Veitch & Sons (A Manual of Coniferae, p. 69, 1881) Engelmann spruce was introduced into England in 1864, where it appears to grow thriftily. Later it was introduced into Germany and extensively tested for its value in forest plantations.

Engelmann spruce was published in 1863, since which time writers on North American trees have generally agreed in maintaining the different wild forms of this tree as one species.

Three or four garden forms of this spruce have been designated as varieties.¹ They are distinguished by their crown habit, size, or the color and length of the leaves.

DISTINGUISHING CHARACTERISTICS.

In dense stands Engelmann spruce has a straight, clean, slightly tapering trunk with a close, very short, narrowly pyramidal crown of small branches; the upper-crown branches are exceedingly short and form a narrow spirelike point. Such trees are from 80 to 100 feet or more in height, and from 18 to 36 inches in diameter. Larger trees occur sometimes, but they are now rather rare. When growing singly or in an open stand, Engelmann spruce has a similarly shaped but longer crown, with drooping lower branches often extending down to the ground. The middle-crown branches are horizontal and the top branches strongly upright. Trees of this form are usually from 60 to 80 feet high, with very tapering trunks, and if exposed to heavy winds the lower branches are often long and stout. From all of the main branches hang numerous tassel-like side branchlets which give the tree a very compact appearance. At high altitudes, Engelmann spruce is often not more than from 2 to 4 feet high, when the spikelike stem bears only a few short, densely leaved branchlets, while enormously long branches grow from the base of the stunted trunk and spread over the ground. The trunk bark becomes scaly even on rather young trees. On older and larger trees it is thin, dark purplish-brown or russet-red, and outwardly composed of very loosely attached small scales.

The foliage of Engelmann spruce is a deep blue-green, that of some trees being decidedly silvery or whitish. This silvery or whitish tinge is very marked on young trees, but occasionally large and moderately old trees still retain it. The 4-angled leaves (Pl. IV, *c*) are rather soft to the touch, usually about an inch in length, but often longer, especially on young, vigorous trees. The leaves are spreading on young twigs and on those which do not bear cones, while on cone-bearing twigs (Pl. IV) they are commonly crowded and usually shorter; they are also often curved so as to appear to grow mainly on the upper side of the branchlet. The point of the leaf is, as a rule, characteristically short and flattish, the short types of leaves exhibiting this more strongly than the longer ones (Pl.

¹ *Picea engelmanni griseifolia* Sudw. (= "*P. e. glauca*"), *P. e. argyrophylla* Sudw. (= "*P. e. argentea*"), *P. e. minutifolia* Sudw. (= "*P. e. microphylla* Hesse"), and *P. e. fendleri* Henry are the garden varieties found in cultivation.

IV, *c*).¹ A cross section of the leaf shows no resin ducts. A disagreeable odor² is emitted by young leaves and young shoots when crushed. The twigs are more or less minutely hairy and remain so for about 3 years.

The cones, which mature in a single season, are ripe by the middle or latter part of August. Most of them are borne near the top of the crown. By October the seed is usually all shed. Cones (Pl. IV) vary greatly in length from about 1 to nearly 3 inches, the usual length being about $1\frac{1}{2}$ inches. The cone scales also are very variable in outline. They are commonly narrowed to squarish ends; sometimes, however, the ends of the scales are pointed, and occasionally rounded.³ When mature, and shortly after shedding their seeds, the cones are somewhat shiny, and vary in color from light brown to dark cinnamon-brown. They fall from the trees during autumn or early winter. The small winged seeds (Pl. IV, *a*) are blackish-brown. The seed-leaves are usually 6 (Pl. IV, *b*).

The wood of Engelmann spruce has thin layers of growth, is soft, straight-grained, and of a very light yellowish to faintly reddish-brown color. The sapwood is comparatively thick and as a rule only a trifle lighter in color than the heartwood. The wood is lighter in weight than that of any other native spruce, a cubic foot of seasoned wood weighing about $21\frac{1}{2}$ pounds. Engelmann spruce is cut extensively for lumber, which is used for general construction and to some extent locally for interior finish. The timber is also much used for temporary or light-traffic ties, telephone and telegraph poles, mine props, fuel, house logs, and corral poles.

OCCURRENCE AND HABITS.

This species is essentially a tree of high altitudes (Map No. 3). Demand for soil moisture limits its occurrence to high elevations or to land moist from springs, seepage, or overflow. The lower range of Engelmann spruce is confined to moist canyons or to protected north slopes, while on other exposures it finds sufficient soil moisture only at higher altitudes. Owing to lower temperatures and less intense light in the North, favorable moisture conditions occur there at lower elevations than in the South, hence, in general, the gradual lowering

¹ Occasionally trees have exceptionally flat leaves with distinctly slender, keen points, in the latter character closely resembling lower-branch leaves of *Picea parryana*. The presence, however, of minute hairs on the twigs serves to distinguish this form from the blue spruce, which has smooth twigs.

² The odor is somewhat like that described for white spruce, but very much less pronounced.

³ *Picea columbiana* Lemmon (Gard. & For., X, 183, 1897) appears to be based upon the northern form of *Picea engelmanni*, in which the cone scales are often more or less rounded at their ends. This form of Engelmann spruce is the one occurring commonly in Montana, Idaho, and British Columbia. Cone scales of Engelmann spruce growing in the central and southern Rocky Mountain States generally have squarish ends.



PICEA ENGELMANNI: FOLIAGE AND OPEN CONES.

a, Upper (left) and lower (right) sides of seeds with wings; b, seedling one week old; c, detached leaves showing variation in length (two and one-half times larger than natural size).

of the tree's altitudinal range of from 8,500 to 12,000 feet in the South to 6,000 feet in the North, with increasing latitude. This variation, however, is not consistent throughout the tree's range, because local climatic factors often have a modifying influence. Trees of merchantable size occur at the middle and lower levels, while chiefly stunted growths are found at timber line. Engelmann spruce shows little preference regarding the character of soil if there is sufficient moisture. It grows fairly well on dry soils, but usually gives way on porous soils to lodgepole pine, Douglas fir, and to other trees requiring better drainage. It thrives on retentive, fine, loamy soils, but attains the largest size on deep, rich, moderately moist soils of gulches and high river valleys. A shallow root-system enables this species to maintain itself on thin soils of slopes and on the wet margins of rivers, lakes, and swamps.

Engelmann spruce forms extensive pure forests and occurs also in mixed stands. Pure stands are somewhat more frequent in the South than in the North, where it chiefly meets trees of similar silvical requirements but of less extended southern range. In mixed stands it is found most frequently with alpine fir, Douglas fir, and lodgepole pine; occasionally it is associated with bristle-cone pine, white fir, and limber pine.

Picea engelmanni is very tolerant of shade, especially in youth, in this respect surpassing most of its associates. It endures years of shading and makes good growth when released from suppression. Owing to its great tolerance of shade this spruce forms close stands of many ages, thus preserving good forest conditions.

Engelmann spruce is a prolific seeder over most of its range. Large crops of seed are produced locally at intervals of about three years. The seed has a high rate of germination and remarkably persistent vitality. Seed so stored as to preserve its moisture and to prevent molding may show a germination of from 30 to 50 per cent after being kept four or five years. Trees begin to produce seed from about the twenty-fifth year and continue bearing it to an advanced age. Seeds germinate best in moist mineral soil, seedlings being rarely found in humus. Notwithstanding prolific seed production, seedlings are not generally abundant. Reproduction appears to proceed rather slowly but persistently, seedlings being most numerous in small protected openings in the forest. Low branches of isolated trees also favor germination and protect seedlings, through which groups of trees are built up, and these combine with other near-by groups finally to form continuous stands.

LONGEVITY.

Engelmann spruce is a very long-lived tree, even in the most unfavorable situations. Trees from 16 to 22 inches in diameter are

from 350 to 460 years old. Stunted trees from 3 to 5 inches in diameter grown on high wind-swept crests are from 150 to 200 years old. Extremely large trees occasionally found would doubtless prove to be from 500 to 600 years old.

BLUE SPRUCE—"COLORADO BLUE SPRUCE."

*Picea parryana*¹ (André) Gardeners' Chronicle.

COMMON NAME AND EARLY HISTORY.

Blue spruce is popularly one of the most widely known North American conifers, and chiefly because of the handsome pyramidal crown form of young trees and the exceptional silvery hue of its foliage, which the common name "blue spruce" aptly describes. Because much of the cultivated stock is raised from seed obtained from Colorado, the tree is frequently called Colorado blue spruce. It was discovered 53 years ago on Pikes Peak, Colo., by Dr. C. C. Parry,² whose name it now bears. In the same year (1862) blue spruce was described for the first time and named "*Abies menziessii* Engelmänn."³ This name had to be abandoned because in 1833 Lindley had applied it to another tree. In 1863 it was named "*Picea menziesii* Engelmänn," which likewise proved to have been preoccupied in 1855. The first tenable name attached to the blue spruce is "*Abies menziesii parryana* André," which was published in 1876, and on which the present accepted name of this tree, *Picea parryana*, is based. Blue spruce is, however, very commonly known to growers of ornamental trees as *Picea pungens* Engelmänn, which was published in 1879.³

¹ The question of what authority should be attached to *Picea parryana* (André), which is based on *Abies menziesii parryana* André (1876), is somewhat perplexing. Recent authors write "*Picea parryana* Sargent," which is presumably based on Prof. Sargent's publication of this combination in *Garden and Forest* (X, 482) in 1897 or on his use of this name in the *Silva* (XII, 47) in 1898. However, the *Index Kewensis* (Fasciculus III, 520) established *Picea parryana* in 1894 by citing as a synonym of it *Picea pungens* Engelmänn (published in 1879), giving "Hort. ex Parry" (in *Gard. Chron.*, XX, 725, 1883) as the authority for *Picea parryana*. Incidentally, Dr. Parry is not responsible for this name, in so far as published evidence is concerned, as reference to the page cited in the *Gardeners' Chronicle* will show, but a nameless writer for the above English journal. "*Picea parryana*" was, therefore, clearly established first in 1883 by this anonymous publication in the *Gardeners' Chronicle*, and there would seem to be no good reason why *Gardeners' Chronicle*, the actual authority for *Picea parryana*, should be ignored. It is perhaps unfortunate that the name of a journal must be cited as authority for a technical name, but strict observance of the facts in this case seems to make it unavoidable.

² Sargent, *Silva*, XII, 48.

³ The first trees cultivated in this country were probably raised from seed which Dr. Parry sent to the Botanic Garden of Harvard University, Cambridge, Mass., in 1863. (*Gard. Chron.*, XX, 725, 1883.) This and many other later trials of the tree in our Northeastern and Middle Eastern States have shown that blue spruce can be successfully grown in these regions. The fact, however, that the great beauty of crown and the brilliant color of the foliage are gradually lost as the trees grow older limits the lasting usefulness of this species for ornament.

Blue spruce was probably introduced into England in 1877 (*Gard. Chron.*, VII, 48, 562, 1877), where it grows thriftily.

The German Government began testing blue spruce in the latter part of the eighties from seed collected in Colorado, and Dr. Schwappach (*Zeitschr. Forst- und Jagdwesen*, XXXIII, 211, 1901) states that this species is well adapted for forest planting in northern Germany.

DISTINGUISHING CHARACTERISTICS.

The popularity of this spruce for ornamental planting is due to the exceptionally bright silvery-blue foliage³ of some young trees. The brilliant color of young trees is, however, gradually lost as they grow older, the foliage of trees even 25 to 35 years old sometimes being decidedly greenish and lacking in beauty. With age also the early distinctly pyramidal crown, with branches down to the ground, becomes thin and irregular in outline, due to the uneven growth of the branches, and later the lower limbs disappear, leaving from one-fourth to one-half of the trunk clear. The thick, strong branches grow in rather distant circles or whorls about the trunk, and with their many much-branched, stiff, upturned side branches form peculiarly wide, flat sprays, especially in the lower and middle parts of the crown. The trunk is strongly conical. Full-grown trees, which sometimes form, as do some other spruces, two or more separate trunks, are from 70 to 90 feet, or, in specially favorable situations, from 110 to about 130 feet in height. The diameter varies from about 16 to 48 inches, but is commonly from 16 to 24 inches.

The bark of mature trunks is from one-half inch to $1\frac{1}{2}$ inches thick, rather deeply furrowed, and composed of small, thin, elongated scales which are externally weathered to a light ash-color, sometimes with a brownish tint, and a bright red-brown beneath. The similarly colored bark of young trees is much thinner, irregularly broken and roughened by thin scales. The smooth 1-year-old twigs are clear reddish yellow, later becoming grayish, while the large buds, about one-half inch long, are light chocolate brown.

The quadrangular dull gray-green, blue-green, or silvery-white leaves (Pls. V, *b*, and VI, *b*) are stiff and very keenly pointed. As a rule, the latter characters at once distinguish this tree from the frequently associated Engelmann spruce, the leaves of which are bluish, but rarely as stiff and as keenly pointed as those of the blue spruce. The leaves bristle from all sides of the twigs, and are from seven-eighths inch to $1\frac{1}{4}$ inches long on lower branches, particularly of young trees (Pl. V, *b*), and one-half to three-fourths of an inch long on upper cone-bearing branches (Pls. V and VI). A cross section of the leaf shows one resin duct in an angle of the leaf. The leaves of each year's growth remain on the branches for from 8 to 9 years.

The cones, which are produced mainly on the upper fourth or third of the crown, mature in one season, and are from $2\frac{1}{2}$ to $4\frac{1}{2}$

³ Seedlings show great variation in the intensity of the blue color of their foliage, and ornamental tree growers have developed, mainly by selection, at least half a dozen named horticultural "varieties" of this tree, each of which is distinguished chiefly by differences in the color of the foliage, which varies from green to bluish and silvery white. These forms are, however, not fixed in nature and have no stable botanical standing. One of the most brightly colored of these garden forms is the so-called "Koster blue spruce" ("*Picea pungens* var. *glauca* *Kosteri*") propagated extensively in Europe.

inches long (Pl. V, *a*), but usually about $3\frac{1}{2}$ inches. They are ripe by the middle or end of August, the thin, tough scales spreading slightly and shedding their seeds during September. In color the cones are a very light yellow-brown and rather shiny. A few of the empty cones fall during the first winter, but the majority remain on the trees until late autumn of the second season. The small seeds (Pl. VI, *a*) are dull chestnut-brown and have pale yellow-brown wings. Seed-leaves of the blue spruce vary in number from 5 to 6 (Pl. V, *c*).

The sapwood and heartwood are often very similar in color. When distinguishable, the heartwood is pale brownish-yellow to light straw color, while the sapwood is nearly white, the smoothed surface of both having a silklike sheen. Seasoned wood is rather light, weighing about 23 pounds per cubic foot, ranking fifth in weight among our spruce woods. It is moderately soft, brittle, and with narrow, often exceedingly narrow, rings of growth. Owing to the limited supply and the commonly knotty character and otherwise inferior quality of the wood, it is the least valuable of all of our native species for commercial purposes. It is rarely used, except locally for house logs, corral poles and posts, temporary mine props, fuel, and occasionally for railroad ties.

OCURRENCE AND HABITS.

Single trees, small groups, and scattered pure groves of limited size occur along the immediate banks of streams flowing in deep and shallow canyons, and in broad, open, grassy valleys. (Map No. 4.) Occasionally single trees are found several hundred yards away from streams and 200 to 300 feet above the water. The largest trees are always found near water. Blue spruce grows in moderately rich dry to moist gravelly, sandy, or rocky soils, at elevations between about 6,000 and 8,500 feet, sometimes ascending to nearly 10,000 feet. It is associated mainly with Engelmann spruce, alpine fir, and occasionally with narrow-leaf cottonwood.

The light requirements of blue spruce are imperfectly known at present, but it is closely similar in tolerance of shade to the Sitka spruce, yet much less tolerant than Engelmann spruce, black spruce, and red spruce. Seedlings and young trees endure but little shade without a material check to their growth, the most vigorous and full development occurring only in full light.¹ With top light saplings and older trees are able to endure considerable side shade.

Blue spruce is an abundant seeder, producing full crops of cones at intervals of 2 or 3 years. The seed has a rather high rate of ger-

¹ Much disappointment is experienced by those who use this tree for ornament because it does not continue to maintain a full, vigorous crown when planted under the shade of older trees or in close groups. The best form can be produced only by planting single trees, or groups of trees widely spaced, so that they will have full enjoyment of sunlight.





PICEA PARRYANA: FOLIAGE AND RIPE CLOSED CONES.

a, Detached large form of open cone; b, mature leaves of new shoot; c, seedlings two weeks and one month old.





PICEA PARRYANA: FOLIAGE AND PARTLY OPEN CONES.

a, Upper (lower row) and lower sides of seeds with wings; *b*, detached leaves showing variation in shape and length (two and one-half times larger than natural size).

mination and persistent vitality. Reproduction, however, is generally scanty and confined mostly to exposed mineral soil in the immediate vicinity of seeding trees. Scanty reproduction elsewhere near mother trees probably is due to the fact that the light seed is prevented from coming in contact with mineral soil by the dense herbage and other ground cover abundant in the habitat of this spruce. Only seldom is abundant reproduction seen where a seed crop chances to fall on earth slides or on moist soil otherwise exposed.

LONGEVITY.

The blue spruce is apparently a very long-lived tree, some of the largest trees probably being not less than 400, and possibly 600 or more years old. Diameter growth is often extremely slow, trees 4 to 5 inches in thickness having attained an age of from 125 to 135 years, while trees 18 to 22 inches in diameter are from 275 to 350 years old.

GENERIC CHARACTERISTICS OF BALSAM FIRS.¹

The true balsam firs are evergreen trees with conical, often sharp spirelike, dense crowns of heavily foliated branches, which by side branching form wide, flat sprays. They are medium to very large size trees with very straight trunks, which gradually taper to one or two slender leaders. Whorls or circles of rather short small branches grow from the trunks at regular, distant intervals. The cone-shaped or arrowlike heads and straight stems of these trees usually distinguish them at a distance from all other associated conifers. Before the trunk bark is broken or furrowed by age, it is marked by many horizontally elongated, blisterlike resin pockets, which are formed just beneath the smooth surface. These resin pockets are often an inch or more long, and so numerous as to be very conspicuous. No other native trees have this characteristic so plainly marked.² It seems probable that trees of this group were given the popular names "balsam" and "balsam fir" because of the liquid resin which is obtained from the pockets of some species for medicinal and mechanical purposes.³ The winter buds of our native

¹ The class and family relationship of the firs to other cone bearers is fully discussed by the writer in Bulletin 207, U. S. Department of Agriculture, "The Cypress and Juniper Trees of the Rocky Mountain Region," 1915.

² Small resin blisters are sometimes formed in the smooth bark, especially of the upper stems, of young Douglas fir (*Pseudotsuga taxifolia*) and Engelmann spruce. They are, however, rarely, if ever, as large or as numerous on these trees as the "blisters" formed in the bark of true balsam firs (*Abies*). The author is indebted to Prof. E. E. Carter for calling attention to the occurrence of resin blisters in the bark of Engelmann spruce he observed growing in Colorado.

³ In this country the crude resin, commonly called "Canada balsam," is obtained entirely from one species of fir (*Abies balsamea*), and chiefly, if not wholly, in the eastern Provinces of Canada and adjacent sections of northeastern United States. A similar product, commercially known as "Strasburg turpentine," is collected from the European silver fir (*Abies pectinata*), and also from the Siberian fir (*Abies pichta*). The "blisters" of all other firs yield liquid resin of the same general character, differing, however, in the color and odor, due to differences in chemical composition.

fir trees are, with the exception of one species (*Abies venusta*), coated with resin.

The leaves of firs, spirally arranged on the branches, persist for from 5 to 10 years (usually 9), after which the oldest set of leaves (a season's growth) gradually disappears. Branches from which the leaves have fallen are conspicuously marked by smooth circular scars, points where the leaves were once attached. In this respect the firs differ radically from the spruces, the leaves of which when shed leave a projecting portion of their bases attached to the branch, giving the latter a distinctly rough feel and appearance. Leaves on the lower branches of our native firs are mostly flat (in one species triangular) and rounded, notched, or blunt at the end (one species only having needle-pointed leaves). In some species the leaves of lower branches appear to grow more or less distinctly in two ranks (somewhat like the teeth of a comb) on opposite sides of the twigs (Pl. VII), while in other species they clothe the top of the branch (Pl. X). The firs that have a distinctly two-ranked arrangement of their foliage on the lowest branches produce leaves on their middle and upper-crown branches which appear more and more to grow only from the upper sides of the twigs. In the case of firs whose leaves thickly clothe the upper sides of the lower branches there is little change from this arrangement in the middle and upper crown. In all cases, however, leaves of the extreme upper branches are stouter, crowded, and strongly curved toward the upper side of the horizontal twigs, and often keenly pointed or somewhat sharp-pointed (Pl. IX). The stout leaders also have larger, keenly pointed leaves (Pls. VIII, *a* and XII, *a*). It is important, therefore, to note the very dissimilar form, habit, and character of leaves in these three parts of the crown, for leaves of the middle-crown branches (Pl. VIII, *b*) are sometimes different in form and arrangement from those of either the lower or upper crown branches. A cross section of the leaves of firs shows two resin ducts (a distinctly marked ring of cells) usually near the lower surface and close to the edges. In the case of some of our firs, however, these ducts are in the interior of the leaf's tissue, about midway between the upper and lower surface of the leaf.¹ The under surface of the leaves has one or several rows of stomata or minute pores on each side of the raised midrib, and sometimes also on the upper surface.

¹ Resin ducts are scarcely visible to the naked eye, but they can be readily seen in a thin cross section or slice of a fresh leaf viewed under a simple pocket lens. The location of resin ducts is always indicated by two minute drops of resin which ooze from the ducts when a fresh leaf is cut in two. As a rule there is little variation in the characteristic position of resin ducts in leaves taken from different parts of the tree. In the case of three exotic firs (*Abies nordmanniana*, *A. cephalonica*, and *A. pectinata*) resin ducts of the lower and middle-crown branches are near the margin of the leaves, while in leaves of the topmost or fruit-bearing branches the ducts are situated in the interior of the leaf's tissue. (Fide cf. Guinier and Maire, Bull. Soc. Bot. France, LV, 189, 1908.)

The male and female flowers of the firs are produced on different branches of the same tree. Each sort is borne on branchlets of the previous year's growth, the male flowers on the lower-crown branches and the female flowers on the topmost branches of the same tree. Male flowers, which bear pollen, are elongated, cylindrical, scaly bodies hanging singly among the leaves from the lower side of branches. The female flowers, which produce cones and seeds, are short, spherical, rounded or elongated, scaly bodies standing erect and singly on branches of the uppermost part of the crown. The cones, whose erect or nearly erect position is unique and distinctive of all firs, mature in one season. (Pls. IX, XI, and XII, *b.*) During autumn their thin, closely packed, overlapping scales gradually become loosened from the central spikelike axis (Pl. IX, *c*, and Pl. XXIII) and fall away with their winged seeds, two of which are borne under each scale (Pl. XIV, *b*, and Pl. XVII, *b*); no fertile or perfect seeds are borne under scales at the two ends of the cones. The spikelike woody axes of the cones remain attached to their branches for several years. (Pls. IX, *c*, and Pl. XII, *b.*) Morphologically these woody axes are modified twigs. The breaking up of mature cones on the trees is characteristic of no other group of our cone bearers, except the deciduous-leaved *Taxodium* ("cypress") of south Atlantic forests. As the ripe cones of firs break up strong winds may blow the seeds several hundred feet from the parent trees, but as a rule the seeds fall near the mother tree or are wafted not more than 50 or 100 feet away. The seeds have peculiar resin cells, which may be seen by cutting into the seed coat. Under ordinary conditions the vitality of fir seeds rarely, if ever, endures longer than a single season, and as a rule the percentage of germination is comparatively low (50 per cent or less). Seed-leaves (cotyledons, the first foliar organs to appear when the seed germinates) range from 4 to 10 in number and are flat. (Pl. XXIII, *c.*)

Fir trees are of great commercial importance on account of the excellent saw timber the larger species produce, while some of them are important also because they form protection forests on steep slopes at high elevations where few other conifers can live. They are moderately long-lived trees, their age limit ranging from about 200 to 350 years; much is yet to be learned, however, concerning their longevity.

Eleven species of firs inhabit the United States. Six of them occur within the Rocky Mountain region (of the United States and Canada), while four are common to both the Rocky Mountain and Pacific slope regions. One species ranges from the Canadian Rocky Mountain region eastward to the Atlantic coast, where it is common both in our northeastern States and in adjacent parts of Canada. One of

our fir is confined to eastern United States, four to the Pacific slope, and one to our Rocky Mountain region.

The fir trees were represented in geologic times.¹ Many fossil species, not now represented by living forms, are widely distributed from the Upper Eocene to the present. Remains also of an *Abies*like group of trees (*Abietites Hisinger*) are very common in the Lower and Upper Cretaceous periods.

BALSAM FIR.

Abies balsamea (Linn.) Miller.

COMMON NAME AND EARLY HISTORY.

The balsam fir does not occur in our Rocky Mountain region, but is found within the Canadian Rocky Mountain region, and for purposes of completeness is included here without reference to political boundary. Balsam fir extends southward into the United States only from the Great Lakes and north Atlantic regions (Map No. 5). It is locally known in this wide range by a dozen or more common names, the most appropriate of which is "balsam fir," coined from the tree's technical name.

The first published reference to balsam fir appeared in 1664 and was by Pierre Boucher,² who observed it in eastern Canada. The earliest mention of this fir in New England is by John Josselyn,³ who recorded its characteristics ("bark is smooth, with knobs or blisters in which lyeth clear liquid turpentine") in 1673. Balsam fir has the distinction of being the first of North American firs to become known to science, the earliest technical name applied to it being "*Pinus balsamea* Linneus," published in 1753, and on which the present name of this fir, *Abies balsamea*, is based. The tree was, however, cultivated in English gardens as early as 1704, when John Ray, an English writer, published a brief description⁴ in Latin of its botanical characters, but without, as was customary then, giving a technical name to it. The early settlers of eastern Canada and northeastern United States were evidently well acquainted with the balsam fir, for French and English settlers and explorers of those regions described the tree and its resinous product in works published long before it was known to scientific writers.⁵

The botanical history of balsam fir extends over 160 years and includes the application at various dates of 17 different specific and

¹ Fide Dr. Edward W. Berry. See footnote, p. 3.

² Hist. Veritable et Nat. de Moeurs et Prod. du Pays de la Nouvelle France * * * le Canada, ed. 3, 49, 1664.

³ An account of Two Voyages to New England, 65 (ed. 1), 1673.

⁴ "Arboris Balsamum Gileadense fundens," Historiæ Planatarum, Lib. XXV, Dendr. Secundus, p. 8, Vol. III, 1704, by John Ray.

⁵ Balsam fir is said to have been grown for ornament in England as early as 1697, and in Norway in about 1772, where it attained a height of from 50 to about 65 feet.

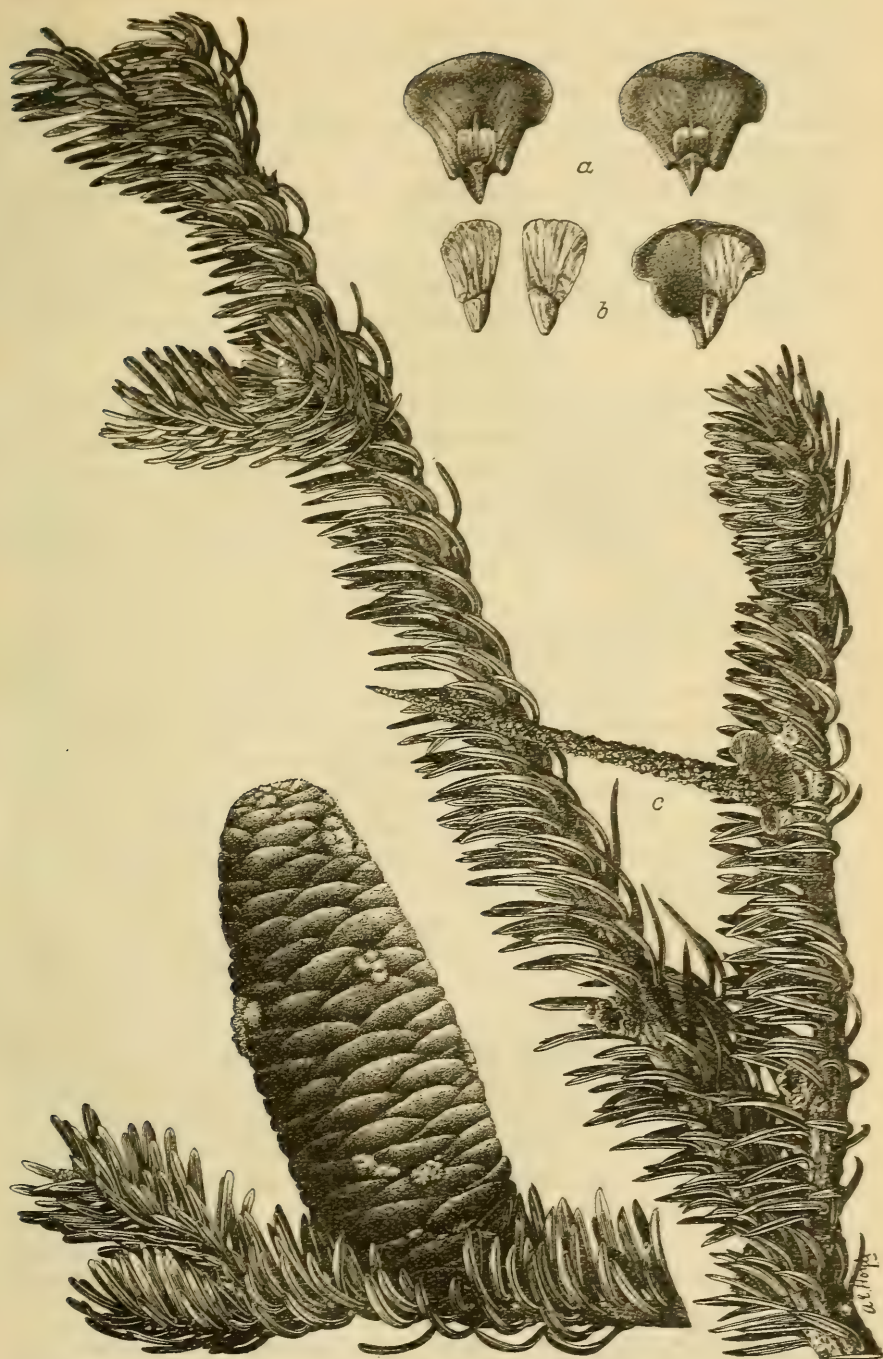


ABIES BALSAMEA: LOWER-CROWN BRANCH.



ABIES BALSAMEA.

a, Terminal shoot ("leader") showing characteristic short, keenly pointed leaves; b, middle-crown branch.



ABIES BALSAMEA: FOLIAGE AND RIPE CONE.

a, Lower side of cone scales with bracts; *b*, upper side of cone scale with one seed in place and upper (right) and lower sides of seeds with wings; *c*, central woody axis of cone from which seed-bearing scales have fallen.



varietal technical names, 6 of which are now reduced to synonymy, and 11 of which (varietal names) distinguish garden or cultivated forms of the tree. These varietal forms are distinguished mainly by differences in the habit of growth, form and size of the crown, and by the color and length of the leaves. One of the best marked of these varieties is a very much dwarfed plant, *Abies balsamea hudsonia* (Knight) Veitch, originally found growing at high elevations. *Abies balsamea* var. *macrocarpa* is a form with longer leaves and larger cones than are borne by the ordinary type of this fir, and was raised from seed of trees found in the region of Wolf River, Wis.

DISTINGUISHING CHARACTERISTICS.

Abies balsamea attains a height of from 25 to 75 feet (under the best conditions for growth), and a diameter of from 10 to 28 inches; exceptional trees are somewhat taller and of slightly larger diameter. Smaller trees, including almost stemless prostrate forms, occur in exposed high places and in other unfavorable situations.

The crown form of young trees growing in the open is broadly conical and ends in a long, sharp point. The branches are slender, regularly arranged in distinct circles or whorls about the trunk, and extend down to the ground. In older trees the lower branches hang down slightly, while those of the upper crown trend upward. When balsam fir grows in a dense stand, the long lower-crown branches are soon shaded out, leaving the gradually tapered trunk clear for one-half to two-thirds of its length and surmounted by a short, rather narrowly conical, sharp-pointed crown. The bark on the lower trunks of mature and middle-aged trees is about one-half inch thick, dull red-brown, and superficially divided into small, rather easily detached, thinnish scales. The bark of young trees, and also of the upper stems of old ones, is smooth and ash-colored and thickly set with resin "blisters,"¹ which, as the bark becomes thicker and older, are gradually dried up and finally obliterated. Young twigs are covered with very fine, short hairs, which adhere until the branchlets are about 3 years old. The mature spherical buds, one-eighth to three-eighths of an inch in diameter, are slightly resinous.

The mature leaves are deep blue-green, shiny on the upper side, and conspicuously whitish (with rows of stomata) on the under side, the latter becoming less bright after the leaves are 2 or 3 years old. Leaves of the lower-crown branches (Pl. VII) differ, as a rule, very greatly in their form and arrangement² on the twigs from both those

¹ The so-called "Canada balsam" of apothecary shops is the crude oleoresin obtained from these pockets or blister-like cavities by puncturing the thin overlying bark and squeezing the contents into a small-mouthed receptacle. Gathering this resin constitutes an industry of considerable importance, especially in eastern Canada.

² Occasional trees are found, especially in the western range of this tree, on which the leaves are more or less crowded on the upper sides of the lower-crown branches, somewhat as in Plate VIII, b.

of the middle-crown branches (Pl. VIII, *b*) and of the upper or cone-bearing branches (Pl. IX), while the thinly set leaves of the terminal shoot or "leader" are strikingly different from all of the other foliage (Pl. VIII, *a*). In length the leaves vary from about $1\frac{1}{4}$ inches on the lower and middle-crown branches to about five-eighths of an inch on the topmost branches. A slightly magnified cross section of the leaf shows two resin ducts, one in each end of the section (edge of leaf), slightly nearer to the lower surface of the leaf.

Mature cones (Pl. IX), which are fully grown and ripe by September, are from 2 to about $4\frac{1}{2}$ inches long and from seven-eighths of an inch to $1\frac{5}{16}$ inches in diameter. At first the ripe cones are externally deep purple, which later become paler as the scales are loosened by drying and fall away from the cone's central axis (Pl. IX, *c*). The bracts attached to the backs of the cone scales (Pl. IX, *a*) are only about one-half as long as the scales. Sometimes, however, the points of all of these bracts extend slightly beyond the ends of the cone scales, while in rare instances some of the cones of a tree may have extended bracts and other cones hidden bracts. The seeds (Pl. IX, *b*) are pale yellowish-brown, as are also the shiny wings.¹

Balsam fir wood is usually of very light weight, soft, and brittle. It is rather wide-ringed in the faster-growing trees of open stands, and narrow-ringed in the slower-growing trees of dense stands. Seasoned wood weighs approximately 23.8 pounds per cubic foot, ranking second in weight among the other Rocky Mountain fir woods. The sapwood is whitish and from 1 to 2 inches thick, while the heartwood is light yellowish brown, sometimes marked with yellow areas. In the central and eastern part of the tree's range the wood is extensively used, in mixture with spruce wood, for paper making. It is also much used for box boards, being rarely cut into other lumber because of its soft texture, knotty character, and lack of durability.

OCCURRENCE AND HABITS.

Throughout its wide range balsam fir grows in soils and under climatic conditions that are quite dissimilar (Map No. 5). In the main, however, it demands an abundance of soil moisture and a humid atmosphere. Lack of these conditions limits its occurrence or greatly impairs its growth. It is most common and of largest size in rich well-drained bottom lands and on adjacent high ground about lakes and water courses, being less common and of smaller size in swampy and low ground, on low hills and benches, on high ridges, and at or near low timber line. The vertical range of balsam fir

¹ The only other Rocky Mountain fir that could be confused with the balsam fir, and then only in Canadian territory, is the alpine fir, which is somewhat similar in size and general appearance. The larger, longer, crowded, upright lower-branch leaves of alpine fir, however, and the horny, little-broken trunk bark of large and medium size trees serve to roughly distinguish this species from balsam fir, the lower-branch leaves of which are commonly arranged on two sides of the twigs, while its trunk bark is loosely scaly.

varies from elevations near sea level to over 5,600 feet. Only low, almost prostrate forms occur, however, at high elevations. The largest trees of this species occur in eastern Canada and in our North-eastern States. In the Canadian Rocky Mountain region balsam fir is a much smaller tree, often closely associated with white spruce, while jack pine, tamarack, black spruce, balm of Gilead, aspen, and paper and mountain birches occur more or less within the same region and are often interspersed with it. Small groups and pure stands of very limited extent occur frequently in deep, rich moist soils of depressions, coves, along streams, and about lakes and ponds.

During the first 6 or 8 years of its life balsam fir is able to grow thriftily in the dense shade of other trees, but during the remainder of its life it requires nearly full top light for the best development. It is much more tolerant of shade in moist soil than in dry situations. Trees continue to live under deep shade for a very long period, but with extremely slow growth. If overhead light is admitted during the period of suppression, the trees recover quickly and resume their normal rapid growth.

Seed is borne abundantly at intervals of 2 and 3 years, and sometimes of 4 years, while considerable seed is produced every year. Trees growing in full enjoyment of the light bear much heavier crops of cones than do those in close stands. Trees long suppressed by shade do not produce seed, doubtless because of the practically arrested growth of the "leader" and upper crown, the only part of the tree that normally produces cones. Pole-size trees (20 to 25 years old) bear a small number of cones, the amount of seed produced increasing as the trees grow older.

The seed has a low rate of germination (15 to 30 per cent) and very transient vitality. Germination occurs plentifully in openings and under the deep shade of the mother trees, where dense groups and thickets of seedlings are frequent as a result of a copious fall of seed. Seedlings are also often thinly scattered. The seed germinates readily in moist exposed soil and humus, but most abundantly on moss-covered decayed logs, in sphagnum, and among other dense herbage, where the even supply of moisture affords the most favorable conditions. Reproduction is always scanty in drier situations. Branches of balsam fir layered in moist soil sometimes strike root, occasionally producing new plants by this vegetative method.

LONGEVITY.

Balsam fir is comparatively short-lived, the largest trees probably not attaining a greater age than 150 years. Dominant trees in a close or open stand grow much more rapidly in diameter than do trees in a close even-aged stand. Diameter growth is still slower in

even-aged stands when the latter are more or less suppressed. Dominant trees 6 inches in diameter in an open stand are about 30 years old, while dominant trees of this size grown in a dense stand are from about 40 to 120 years old. Trees 16 inches in diameter that have grown in an open forest are about 130 years old, while dominant trees 12 inches in diameter grown in a close stand are about 156 years old. Suppressed trees 6 inches in diameter may be from about 50 to 75 years old, according to the density of overhead shade. In exceptional cases wholly suppressed trees 2 to 3 inches in diameter may be from 75 to 100 years.

ALPINE FIR.

Abies lasiocarpa (Hook.) Nuttall.

COMMON NAME AND EARLY HISTORY.

Alpine fir is one of the smallest of the western firs and perhaps also one of the least known there, owing to the fact that it grows chiefly at high altitudes. The common name, "alpine fir," adopted here, would seem to be the most appropriate one for this species, because it refers to the tree's high mountain habitat.¹ Woodsmen and settlers usually call it "balsam" or "mountain balsam."

It is probable that alpine fir was first discovered in September, 1805, by Lewis and Clark, while crossing the Bitter Root Mountains (whether on the Montana or Idaho side is unknown), for the narrative² of their exploration of our Northwest mentions "a growth of eight different species of pine," which by exclusion must have included this fir.³ To David Douglas belongs the credit of having first collected a specimen of this fir in 1832 in the "interior of N. W. America." On this specimen is based the first published technical description and name of the tree, "*Pinus* (*Abies*) *lasiocarpa* Hooker," published in 1839, and on which the present name, *Abies lasiocarpa* (Hooker) Nuttall, is founded. Dr. C. C. Parry⁴ seems to have been the first to find alpine fir in our central Rockies (Colorado), where he observed it in 1862, and from which in 1863 he distributed seed.⁵ It was not known, however, until 1876 that the

¹ *Abies lasiocarpa* is frequently called "balsam fir," probably because of its general resemblance to the true balsam fir (*Abies balsamea*), to which, however, this name properly belongs, having been applied to it long before the alpine fir was known to botanists.

² History of the Expedition under Command of Lewis and Clark, 1804-1806 (ed. Dr. Elliott Coues), II, 598.

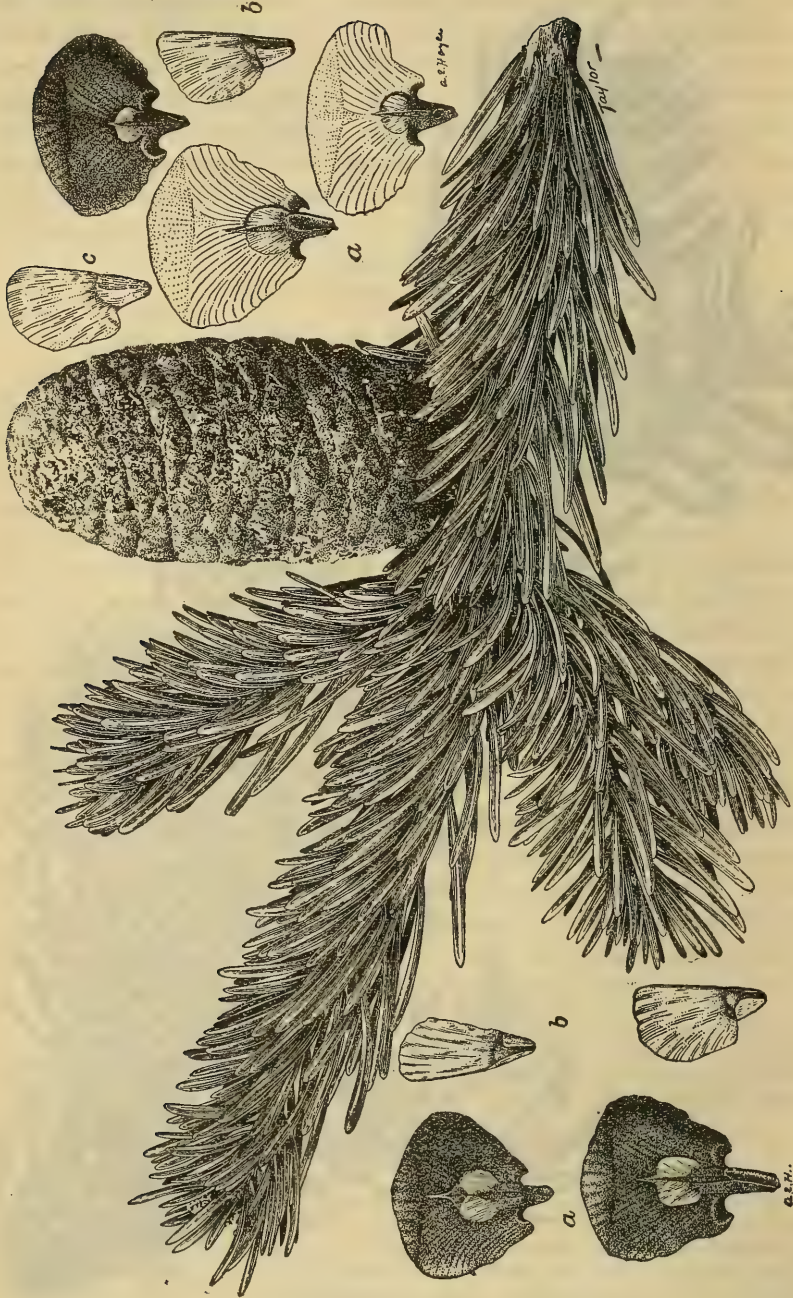
³ It was common in the early days, even for botanists, to designate as "pine" the trees we now know as firs.

⁴ Engelmann in *Am. Nat.*, 555, 1876.

⁵ There appears to be no record of plants raised from this seed. Probably the first trees known in cultivation were grown from seed planted in 1873 in the Arnold Arboretum, Massachusetts. Their growth in height for the last 40 years has, however, been exceedingly slow, amounting to only about 3 or 4 inches per year. Alpine fir seems to have been introduced into England in about 1890, but according to Elwes and Henry (Trees of Great Britain and Ireland, IV, 803, 1909) its growth there has been practically a failure. The German Government imported seed of this fir for forest experiments in the early nineties, and these trials show the tree to be better adapted to the climate of Germany than to that of England.



ABIES LASIOCARPA: LOWER-CROWN BRANCH.



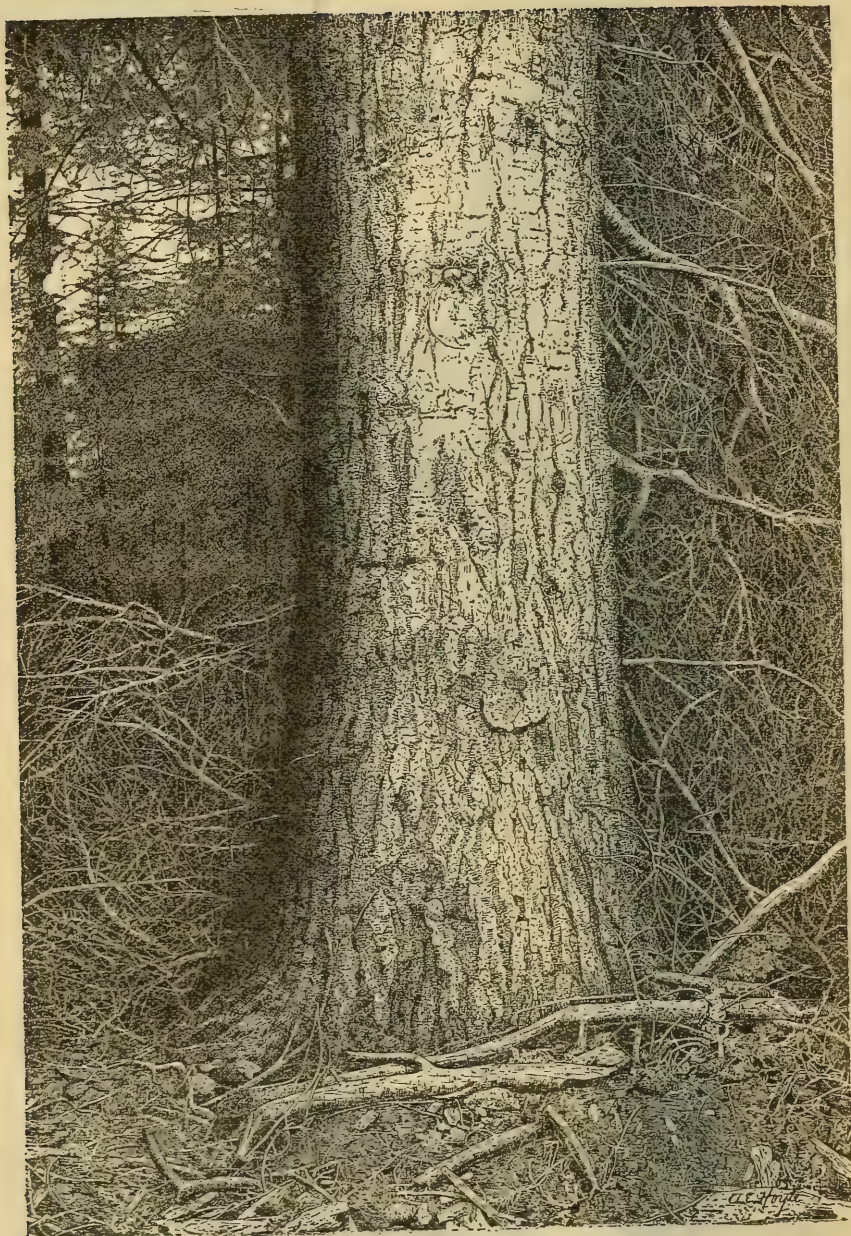
ABIES LASIOCARPA: FOLIAGE AND RIPE CONE.

a, Lower side of cone scales and their bracts, showing variation in form of latter; b, lower side of seed; c, upper side with wings.



ABIES LASIOCARPA.

a, Terminal shoot ("leader") showing characteristic sharp-pointed leaves; *b*, top of tree showing ripe cones and naked cone spikes of previous year's crop.



. ABIES LASIOCARPA: TYPICAL BARK OF MATURE TREE.

tree he saw there is the same as Nuttall's *Abies lasiocarpa*.¹ A cultivated variety of alpine fir, *Abies lasiocarpa caerulescens*, was described in 1891 by a German dendrologist. This form is distinguished by the deep silvery-blue tint of its foliage, a characteristic which is, however, largely lost as the leaves become fully mature, and is not as marked in older trees as in young ones.

DISTINGUISHING CHARACTERISTICS.

The long, narrowly conical crown, terminating in a conspicuous spearlike point (Pl. XII, *b*), at once distinguishes this fir from all associated species of its kind in the region, its sharp-pointed heads being recognizable at a long distance. The height attained is ordinarily from 60 to 90 feet and the diameter is from 14 to 24 inches, but in exposed high situations the stems may be under 4 feet in height, with very long lower branches resting on the ground. Rare old trees attain heights of from 100 to 130 or, very occasionally, 160 feet and a diameter of 3 to 4 feet. Still larger trees are reported, but they are exceedingly rare. The trunk bark is thin, at most about $1\frac{1}{4}$ inches thick, hard, flinty, and but little broken even on fairly large trees, except occasional shallow, narrow cracks near the base of the trunk (Pl. XIII). The unbroken smooth areas of bark are ashy gray—often chalky-white. Even on old trunks, always irregularly and shallowly seamed, the flat ridges of bark are whitish, but pale-brownish in the seams, while the inside of the bark is red-brown.

In open stands the narrow crowns of both young and old trees usually extend down to the ground. In very close stands the trunks of old trees are occasionally free from branches for from 20 to 40 feet or more (Pl. XIII). The dense, characteristically tough branches at the base of the crown droop, and later when they die they are often sharply curved or bent down upon the trunk.²

The foliage is deep blue-green, that of each season's growth having a silvery tinge. The twigs are usually covered with minute, rusty hairs for 2 to 3 years, or sometimes they are smooth. The winter buds are covered with resin. The flat leaves, pointless and longer on lower-crown branches (Pl. X), and keenly or somewhat pointed and shorter on uppermost branches (Pl. XI), are distinctly massed and pointing upward on the top side of the branches, those below and on the sides of the branches being curved so as to joint those above. This dense

¹ Dr. George Engelmann (l. c.) described and named this fir "*Abies sub-alpina*" in 1876, a name which is now a synonym of the earlier published *A. lasiocarpa* (Hook.) Nuttall.

² The low branches make this fir particularly subject to crown fires, which invariably kill large numbers of trees, while the thin bark of the trunk is also frequently injured or killed by severe ground fires.

crowding and upright position of the leaves on the upper sides of the branches is very characteristic. Leaves of the "leader" or topmost central stem (Pl. XII, *a*) are sharply pointed and scattered.

Mature cones of the alpine fir are from $2\frac{1}{4}$ to about 4 inches in length by about $1\frac{1}{4}$ to $1\frac{1}{2}$ inches in diameter (Pl. XI); after the cone scales become loosened by drying out, the cones are considerably larger in diameter. Ripe cones are deep purple at first, gradually becoming lighter by the time the scales fall. The cone scales bear bracts (Pl. XI, *a*), which are abruptly rounded or contracted at the free end to a slender central point. The ivory-brown seeds (Pl. XI, *b*) have large, shiny, purplish, or violet-tinged wings. The seed-leaves, one-third to one-half an inch long, are usually 4 in number.

Alpine fir wood is lighter in weight than that of any other Rocky Mountain fir, a cubic foot of dry wood weighing about 21.66 pounds. It is narrow-ringed, soft, and from pale straw-color to light yellowish brown. As a rule, the wood is fairly straight-grained and splits and works easily, but it rots rapidly in contact with earth. However, the fire-killed, deeply season-checked shafts of this tree, so frequent where forest fires have swept the ground, may remain sound above ground for many years. Dead timber is locally much used for fuel, house logs, and corral poles. Occasionally green timber is sawed into rough lumber for local use. Little clear lumber is, however, obtainable even from large trees, because during the greater part of life the lower trunk branches are retained down to the ground.

OCCURRENCE AND HABITS.

Alpine fir always grows in cool, moist, and, in part, subalpine situations. It occurs commonly on all slopes at timber line, and, at the lower limits of vertical range, in protected valleys, at the heads of streams, and about mountain lakes and moist meadows (Map No. 6). At the North its lowest vertical range is about 3,500 feet, though at the South it may reach an elevation of 10,500 feet. Alpine fir has a narrow range in altitude at the North, where the timber line is relatively low, and at and near which the moisture conditions necessary for its growth are present. Likewise at the South, the vertical range of this fir is narrow, because here the timber line, with the accompanying moisture conditions, occurs only at higher elevations. The best growth occurs on north slopes in fairly deep, loose, moist soil, while much smaller trees are found in the poorest and driest thin soils. It grows also in wet situations, but it does not thrive on heavy, clayey soils. Its main occurrence is limited by requirement of soil moisture to elevations where snowfall is heavy. In general, how-

ever, alpine fir requires less soil moisture than Engelmann spruce, but grows in places too wet for this spruce; it also grows on soils suitable for Douglas fir, where Engelmann spruce will not succeed.

Alpine fir occurs in pure small stands and in mixture with other trees. At the North it is associated more or less with mountain hemlock, Engelmann spruce, lodgepole pine, white-bark pine, limber pine, and Lyall larch. At the south it is mingled commonly with Engelmann spruce, lodgepole pine, cork fir, and aspen, and less frequently with bristle-cone pine.

Alpine fir is only slightly less tolerant of shade than Engelmann spruce, and, except the mountain hemlock, it can live under deeper shade than any of its associates. Saplings long suppressed by heavy shade recover and grow rapidly with the admission of top light.

Abies lasiocarpa is a moderately prolific seeder, beginning to bear cones as early as the twentieth year. Some seed is produced locally every year, but heavy production occurs only at intervals of about 3 years. The seed has a rather high rate of germination, but very transient vitality. Seedlings spring up abundantly on exposed mineral soil in the open and also on thin and heavy moist duff under light or heavy shade. Usually, however, they grow most thickly on the north side of groups of trees or forests and under the branches of mother trees. Abundant reproduction nearly always occurs in shaded openings among seed trees. At high elevations branches lying on the ground and partly covered with earth or moist duff occasionally take root, from which, however, the production of new trees is probably very rare.

LONGEVITY.

Alpine fir is moderately long-lived. Trees from 10 to 20 inches in diameter are from 140 to 210 years old. The considerably larger trees which occur are not likely to be more than 250 years old.

CORK FIR.

Abies arizonica Merriam.

COMMON NAME AND EARLY HISTORY.

Most authors consider this fir a form only or a variety of the alpine fir (*Abies lasiocarpa*). For the present, however, it is here maintained as specifically distinct from the alpine fir, to which it is very similar in crown form and in the general appearance of its foliage, but from which it is at once distinguished by its soft, corky bark (compare Pls. XIII and XV), differences in the shape of the

cone scales and of the bracts¹ (compare Pls. XI, *a*, and XIV, *a*). The book name "Arizona cork fir" has not become established, and can well be replaced now by the shorter and more fitting name "cork fir." "Arizona cork fir" is a name particularly inappropriate, because the tree is not confined in its range to Arizona.

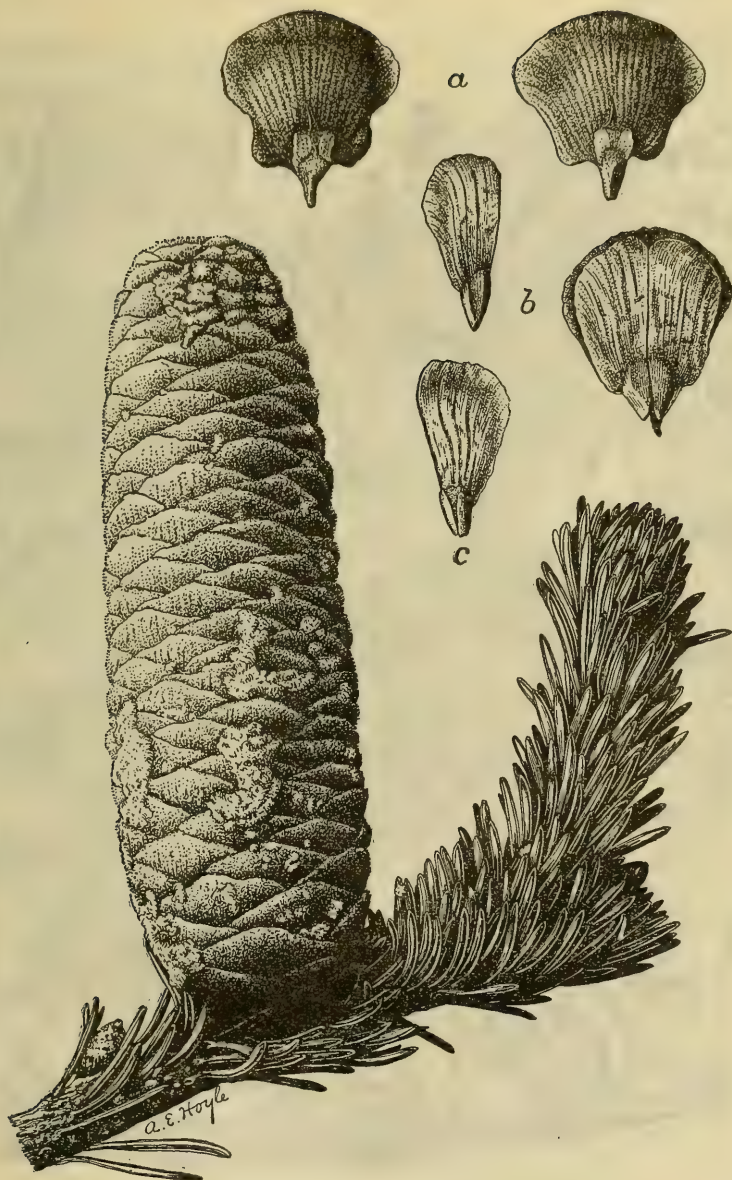
Abies arizonica was first discovered in 1896 by Dr. C. Hart Merriam² on a high peak of San Francisco Mountain, Ariz. Since then its range has been considerably extended in Arizona, and the tree is now known to occur in New Mexico and southern Colorado (Map No. 7). Future explorations are likely to extend this range still farther in the southern Rocky Mountain region.

DISTINGUISHING CHARACTERISTICS.

As now known, cork fir attains a height of from 50 to 75 feet and a diameter of from 12 to about 20 inches. Doubtless larger trees occur. The trunk and crown forms are practically the same as in the alpine fir. The yellowish-white or ashy, soft, corky trunk bark (Pl. XV) of *Abies arizonica* at once distinguishes this tree from *A. lasiocarpa* (Pl. XIII) and from all other associates. The form and habit of the leaves of the cork fir and Alpine fir are so similar in general appearance that the two trees can not be distinguished by their foliage. The cones (compare Pls. XI and XIV) of the two trees are more or less dissimilar in form and size, but alike in color, and both ripen at about the same time in September. The cone scales of *A. arizonica* are, however, generally of a distinctly different form (Pl. XIV, *a*) from those of *A. lasiocarpa* (Pl. XI, *a*), while

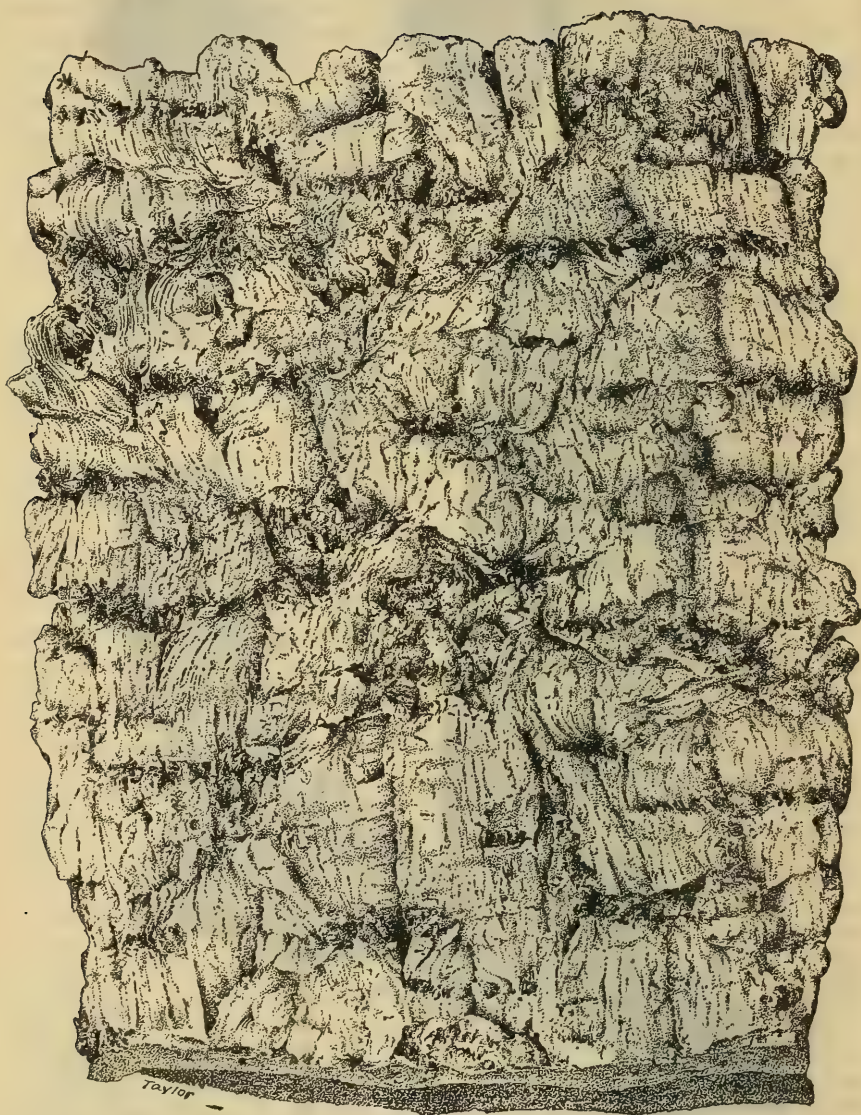
¹ Writers who hold this tree to be a form only of the alpine fir seem not to give due weight to the fairly constant difference in the form of the cone scales and bracts of the cork-barked tree as compared with the shape of cone scale and bracts peculiar to the alpine fir. The specific importance of the distinctly corky bark of *Abies arizonica* is also denied by citing the occurrence of similar corky bark of southern Rocky Mountain forms of white fir and of Douglas fir, and, furthermore, that corky-barked Alpine fir trees occur far north and west of the present range claimed for *Abies arizonica*. While it is true in general that the bark of many trees is so variable in character as not to afford a reliable specific distinction, it is true nevertheless that a large number of trees have barks of very distinct character. I have often seen Douglas fir and white fir in the Southwest, especially in dry, exposed situations, with corky bark, but not of the distinctly corky nature of bark produced by *Abies arizonica*. I believe, however, that the corky bark of Douglas fir and white fir is the result of arid conditions, which appear to affect young trees, the corky bark so formed later becoming harder as these trees grow older. In the case, however, of *A. arizonica*, I do not know that the bark ever becomes harder or less corky. Taking into account the fact that the cone scales and bracts of *A. arizonica* are usually distinct in form from those produced by *A. lasiocarpa*, I am confident that the occurrence of corky-barked Douglas fir and white fir trees is a circumstantial coincidence rather than proof that *A. arizonica* is only a corky-barked form of *A. lasiocarpa*. I have never seen the cork-barked alpine fir trees reported as occurring north of Colorado and elsewhere outside of the present recorded range of *A. arizonica*. I should be inclined to believe, however, that these trees represent Dr. Merriam's *Abies arizonica*, rather than corky-barked forms of *A. lasiocarpa*. Otherwise I am unable to satisfactorily explain why, in Colorado, New Mexico, and Arizona, *A. arizonica* occurs side by side with the distinctly hard-barked *A. lasiocarpa*, a fact which would seem to indicate that the cork-barked tree is inherently different from its associate.

² Proc. Biol. Soc. Washington, X, 115, figs. 24, 25, 1896.



ABIES ARIZONICA: FOLIAGE AND RIPE CONE.

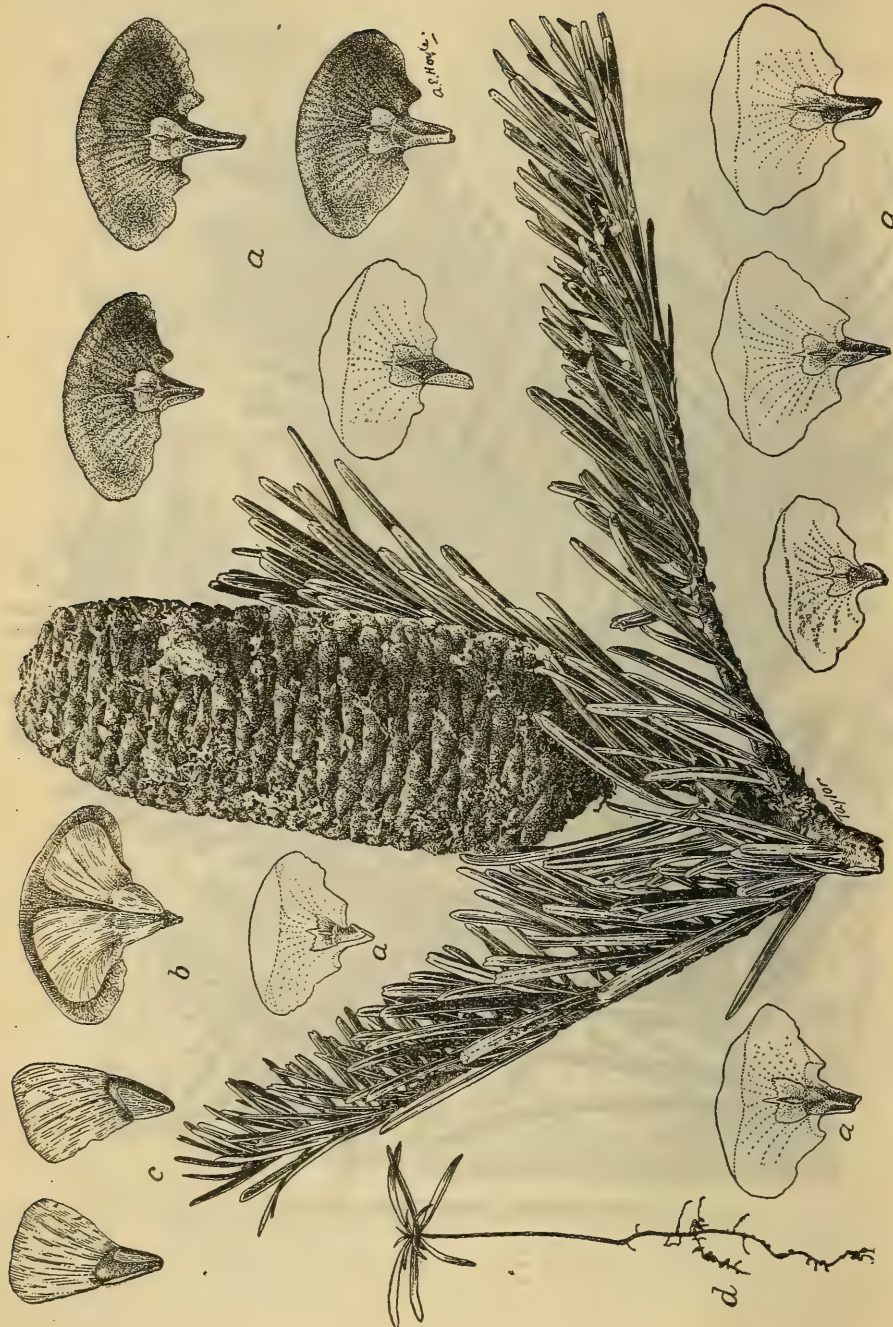
a, Lower side of cone scales and their bracts; *b*, upper side of cone scale with its winged seeds (as they are borne) and detached seed; *c*, lower side of seed.



ABIES ARIZONICA: SECTION OF TYPICAL CORKY BARK OF TRUNK.

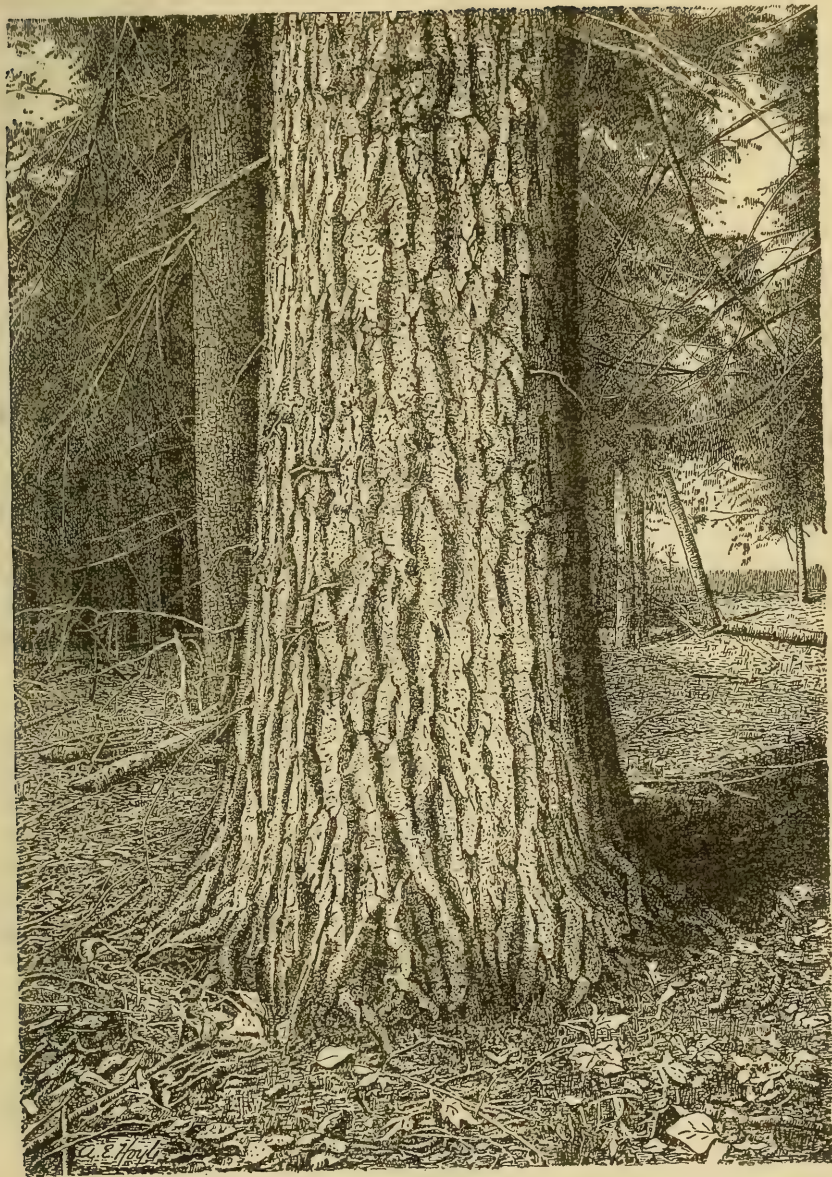


ABIES GRANDIS: LOWER-CROWN BRANCH.



ABIES GRANDIS: FOLIAGE AND RIPE CONE.

a, Lower side of cone scales showing various forms of their bracts; b, upper side of cone scale and its winged seeds (as they are borne); c, lower side of seeds; d, seedling about six months old.



ABIES GRANDIS: TYPICAL BARK OF TRUNK.

the bracts borne on the backs of the cone scales of both trees also differ materially in form. No constant distinguishing characters can be found in the seeds (Pl. XI, *b*, *c* and Pl. XIV, *b*, *c*). The seed-leaves of cork fir are commonly four in number, and about one-half an inch long.

The wood of *Abies arizonica* is similar in external appearance to that of alpine fir and useful for the same purposes. It is commercially unimportant, except where the timber can be cut with alpine fir, from which when sawed into lumber it can not be distinguished in its general appearance.

OCCURRENCE AND HABITS.

Cork fir grows on disintegrated rock and in gravelly soils or on thinly covered rock at elevations between about 8,000 and 10,000 feet, and usually on northern slopes and benches, but sometimes on exposed ridges and high peaks (Map No. 7). In some instances it forms nearly pure groups or stands of limited extent interspersed with Engelmann spruce and alpine fir, or is scattered in dense stands of the latter tree. Not infrequently very widely separated trees are found in a mixed stand of Engelmann spruce and alpine fir.

Cork fir is equally as tolerant of shade as the alpine fir, young trees maintaining themselves for many years under dense shade in a completely suppressed condition. But with the admission of top light such growths readily recover and grow rapidly.

Little is known at present of the seeding habits and reproductive capacity of this fir. An abundance of cones are produced periodically—usually about every 3 years, while some trees bear a few cones nearly every year. Only a small percentage of the seeds are fertile. The ripe cones are “cut down” by squirrels, along with those of the associated alpine fir, and a good many seeds are eaten by these rodents. Small dense patches of suppressed seedlings are frequent near fruiting trees, particularly in the washed soil of depressions and in the soil-filled crevices of exposed rock on northern slopes.

LONGEVITY.

The age limit of cork fir is imperfectly known at present. Like alpine fir it is probably only a moderately long-lived tree, not exceeding 150 to 175 years. Trees from 6 to 12 inches in diameter are from 45 to 90 years old.

GRAND FIR—“WHITE FIR.”

Abies grandis Lindley.

COMMON NAME AND EARLY HISTORY.

Lumbermen and other woodsmen know this tree commonly as “white fir,” because of the whitish, smooth bark of its upper stem.

The name white fir, however, belongs more properly to *Abies concolor*, for which it is probably more commonly and widely used than for any of the other white-barked western firs. It is probable that lay people often apply the name white fir to *A. grandis* believing it to be *A. concolor*. In the absence of a distinctive common name for *A. grandis*, "grand fir," derived from the tree's specific technical name, is adopted here as suitable, because *Abies grandis* is a very stately and grand tree when fully matured.

Lewis and Clark¹ were probably the first to discover the grand fir in 1805 while crossing the Bitter Root Mountains, this tree doubtless being one of the "eight different species of pine" mentioned in their narrative. David Douglas, an intrepid Scotch explorer of our Northwest, is said to have found this fir near the mouth of the Columbia River in 1825, seeds of which he sent to England in 1831 or 1832.² The grand fir was first technically described and named *Abies grandis* Lindley in 1833, since which time this name has been uniformly maintained by botanists. Some early writers, however, confused grand fir with the white fir (*Abies concolor*), while even now a few students of trees find difficulty in distinguishing the two species where their ranges come together.³

Two horticultural varieties of grand fir, *Abies grandis aurifolia* and *A. grandis crassa*, have been distinguished in cultivation by a German dendrologist. The first of these is characterized by its yellowish foliage and in the other form by the compact shape of its crown.

DISTINGUISHING CHARACTERISTICS.

In such favorable situations as moist bottom lands grand fir grows to a height of from 150 to 200 and, exceptionally, 250 to 275 feet, with a diameter of from 3 to 4 feet. Somewhat taller trees occur, but they are rare. On the less favorable hill lands the greatest height attained is from 80 to 125 feet, with a diameter of from 18 to 30 inches. The trunk is remarkably straight and tapers very gradually. When standing alone or in an open forest even old trees often retain their branches down to within a few feet of the ground; but in a close stand the crown covers only one-half or one-third of the stem. The crown is a narrow, rather open cone, pointed in young trees and somewhat rounded at the top in old ones. Because of the strong drooping of the lower branches, the crown of old trees appears wider in the middle. The rounded top of well-advanced

¹ History of the Expedition under Command of Lewis and Clark, II, 457 (ed. Coues).

² Elwes and Henry, Trees of Great Britain and Ireland, IV, 774, 1909.

³ *Abies grandis* was first introduced into England in about 1831, and, according to Elwes and Henry (l. c.), it grows best of all of our fir trees in England, Scotland, and Ireland, where there are many trees 80 to 90 feet high planted 40 to 50 or more years ago. It is also said to thrive in parts of Denmark and Germany.

trees results from the cessation of height growth in the leader and an elongation of the older, shorter, upper side branches. All of the branches, except the topmost, have a distinct downward and upward swing. The bark, peculiarly characteristic in this species, is smooth and ashy-brown, with chalky areas on young trunks and regularly and shallowly furrowed on older trees, the long, flat ridges still retaining splashes of gray-white. (Pl. XVIII.) The bark of very old trees is still more deeply but narrowly furrowed, the ridges being sharper and less conspicuously flecked with white and the general tone pale red-brown with an ashen tinge. In texture the bark is very hard, close, and horny. It is rarely over $1\frac{3}{4}$ inches thick on old trunks and scarcely an inch thick on trees from 18 to 20 inches in diameter.

The deep yellow-green shiny foliage of grand fir is somewhat thin in appearance because of the characteristic two-ranked arrangement of leaves on the lower branches. Leaves on these branches are flat, grooved above, blunt, and nearly always distinctly notched at their ends (Pl. XVI). They appear to grow only from two opposite sides of the branches, but many of the leaves are brought into this position by a twist at their bases. Leaves of the lower-crown branches are from about one-fourth inch to $2\frac{1}{4}$ inches long. Leaves of the uppermost branches also are often notched; but here they are usually crowded together in a more or less upright position on the top sides of the sprays and are from about 1 to $1\frac{1}{2}$ inches long (Pl. XVII). The scattered leaves of the leader are sharp or keenly pointed and from one-half to seven-eighths of an inch long. All leaves are conspicuously white on their under surfaces. The mature winter buds are covered with resin, and the twigs of the season are pale russet-brown and minutely hairy.

The cones of this fir mature in early autumn, and are very characteristic in their clear, light yellow-green color and slender, cylindrical form (Pl. XVII). They are about $2\frac{1}{2}$ to $4\frac{1}{4}$ inches long and about 1 to $1\frac{1}{3}$ inches in diameter. The bracts of the cone scales are relatively broad and usually squarish (truncated) at their upper ends (Pl. XVII, *a*), or occasionally somewhat heart-shaped or notched at the top end with a small tooth-like point extending from the center. The pale yellowish-brown seeds (Pl. XVII, *b*, *c*) have shiny, faintly yellowish wings. The seed-leaves, which are very slender and pointed, are usually six in number, and about three-fourths of an inch long (Pl. XVII, *d*).

The wood of grand fir ranks fourth in weight among Rocky Mountain fir woods, a cubic foot of dry wood weighing about 22 pounds. It is soft, but firm enough to be useful as lumber, moderately wide-ringed and straight-grained. In color it varies from pale

yellowish-brown to very light brown. The wood of this fir is little known in the Rocky Mountains and is only occasionally cut for lumber in the Pacific slope region, though its good quality entitles it to be better known and more widely used. The ease with which the wood can be worked, and other good physical qualities, render it the equal, if not the superior, of the softer fir woods now cut for lumber.

OCCURRENCE AND HABITS.

Grand fir is essentially a tree of moist situations. It grows most commonly on alluvial stream bottoms and adjacent higher ground, lower gentle mountain slopes, depressions, and gulches, at elevations between about 2,000 and 7,000 feet (Map No. 8). The best and most abundant growth occurs on stream bottoms at the lower levels, much smaller trees being found at high elevations. Its deep root system demands permeable, preferably moist, porous, well-drained soils. With favorable moisture and climatic conditions grand fir grows well on rather poor, thin soils, but better quality is necessary in soils deficient in moisture and subject to rapid evaporation.

Grand fir rarely occurs in pure stands, except of limited extent. Usually it is mixed with western white pine, lodgepole pine, western larch, Engelmann spruce, mountain red cedar, western yew, Douglas fir, black cottonwood, balm of Gilead, and sometimes with western yellow pine. The number of species and the percentages of the stand they represent in this association vary greatly in different localities within the general range of grand fir. It is always dominant when associated with mountain red cedar.

Grand fir is the least tolerant of shade, with one or two exceptions, of all of our fir trees, growing only moderately well under such conditions. It is much less able to live under the shade of other trees than the mountain red cedar, western hemlock, and western yew, but much more tolerant than Douglas fir, western white pine, western larch, and western yellow pine. Seedlings endure considerable shade for several years, but unless they are given full overhead light, such growths become dwarfed and die within a few years. With overhead light, the height growth of this fir is rapid, and under side shade the trunks are readily cleared of branches, forming the characteristic long, clean stems. Endurance of shade, however, varies in general with age, exposure, moisture of the soil and air, quality and quantity of available soil, altitude, and latitude. The largest trees are products of sufficient moisture, soil, heat, and full sunlight. Under these conditions it will also endure considerable shade. On poor, dry soils and in warm exposed places, shelter from cold winds and some shade are beneficial in reducing soil evaporation and transpiration;



ABIES CONCOLOR: LOWER-CROWN BRANCH OF YOUNG TREE.



ABIES CONCOLOR: LOWER-CROWN BRANCH OF OLD TREE.

therefore in regions with such conditions the tree confines itself mainly to cooler northern slopes and other protected sites.

Abies grandis is a fairly prolific seeder, trees in open stands fruiting most heavily. Seed is produced mainly at irregular intervals of about 2 or 3 years; whether or not this species has the habit of regular periodic seed production is, however, not fully determined. Trees grown in the open occasionally produce a few cones when they are about 20 years old, seed production increasing thereafter up to old age. The seed has a rather low rate of germination and only transient vitality. Under favorable conditions some seed germinates soon after it falls to the ground, and seedlings may become established before cold weather. Moderately humous, shaded soils are most favorable to germination, but with sufficient moisture and light, seeds sprout readily and seedlings thrive in either pure humus or mineral soils. Seedlings come up both in the open and in shady places.

LONGEVITY.

The extreme age limit of this fir is unknown. It is probable, however, only a moderately long-lived tree, possibly attaining an age of from 200 to 250 years. One tree, $34\frac{3}{4}$ inches in diameter, showed an age of 196 years.

WHITE FIR.

Abies concolor (Gord.) Parry.

COMMON NAME AND EARLY HISTORY.

Abies concolor is a massive tree fitly and widely called white fir because of the light ashy hue of its bark. A few other local common names applied to it, such as "silver fir," "white balsam," etc., also refer to this characteristic.

The white fir was first discovered in the southern Rocky Mountain region by a Russian collector of plants named Augustus Fendler,¹ who found it in 1847 near Santa Fe, N. Mex., while exploring there under the protection of United States troops stationed in that country during our war with Mexico. It was not discovered in our Pacific slope country, where its more extensive range lies, until 1851, when John Jeffrey collected specimens of the tree in northern California.² The first technical name applied to white fir, the one it now bears, was published in 1850, but without a botanical description, an omission which left this name legally unestablished until 1875. The earliest properly established technical name applied to white fir is "*Picea concolor* Gordon," which was published in 1858, and on which

¹ Asa Gray, in *Am. Journal of Sci.*, xxix (ser. 3), 169; *Canby Bot. Gaz.*, x, 285, 301.

² Sargent, *Silva*, XII, 124.

Abies concolor (Gord.) Parry is technically based. Botanists have generally maintained this name, although since its establishment some fifteen other specific and varietal names (now made synonyms of *A. concolor*) have been published. These names were created chiefly, however, either through confusion of the white fir with other North American firs, or through imperfect knowledge of the variable forms of the tree peculiar to different parts of its extensive range.¹

One of the best marked varietal forms of white fir well known in cultivation is *Abies concolor lowiana* (Murr.) Lemmon. It has short pale green foliage and occurs in the California Sierras and in the Siskiyou Mountains of southern Oregon. European dendrologists have segregated five other cultivated varieties, chiefly by the color of their foliage, shape of the leaves, and habit of the crown or of its branches. The characters relied upon to distinguish these latter garden forms do not, however, appear to be sufficiently dependable to warrant maintaining the plants as distinct varieties.

DISTINGUISHING CHARACTERISTICS.

White fir grows to its largest size in the Pacific region, where it is frequently from 140 to 180 feet, and occasionally over 200 feet, high, with a diameter of from 40 to 60 inches, rare trees being from 5 to 6 feet through. In its Rocky Mountain range, however, white fir is a much smaller tree, at best being only from 80 to 100 feet in height, or rarely more, and from 20 to 30 inches in diameter. The massive trunks have conspicuously rough ash-gray bark, which is broken into great, deep, wide furrows and ridges. The bark is very hard and horny and from 4 to 6½ inches thick on the largest trunks (Pl. XXIV). Bark of the upper stems of large trees and on young trees is smooth and unbroken and grayish, with a slight brownish tinge. The trunks are straight and taper very gradually. The dense crown of heavily foliated short branches is an irregular, round-topped cone, extending to the ground on trees in open stands, while in dense stands the crown covers only one-third or one-half of the stem. Young trees have beautifully symmetrical, sharp crowns extending down to the

¹According to Elwes and Henry (Trees of Great Britain and Ireland, IV, 780, 1909), the California form of white fir was first introduced into England in 1851, while the Rocky Mountain form of this species was introduced there in about 1872. Trees raised from California seed are said to grow more thriftily in England than stock from Rocky Mountain seed. One tree in Oxfordshire attained a height of 71 feet and a diameter of about 2 feet in 28 years. The largest trees growing in England are from about 70 to 90 feet in height and from 20 to 40 inches in diameter. The German Government purchased considerable quantities of white fir seed, both of the Rocky Mountain and Pacific slope forms, in the early nineties for experimental forest planting in Germany, but the results of these trials are unknown to the writer at present. Doubtless the Rocky Mountain form has proved more adaptive to German conditions, judging from the excellent growth of Douglas fir from this region and the failure there of Douglas fir plants raised from Pacific slope seed. White fir from the Rockies and the Pacific slope grows thriftily in eastern United States but stock from the interior mountains is far better adapted to this region than the more western form, while for ornamental planting the Rocky Mountain trees are much handsomer in form and in bluish-tinged foliage.

ground, the lower limbs standing out horizontally and those above trending upward. Six to ten year old trees have not yet assumed this sharp-pointed form of crown, and all of their branches are commonly at right angles to the stems (Pl. XXIII, *d*). On old trees the lower-crown branches droop conspicuously, as do also those of the middle crown; while branches above this trend upward. In old age the extremely slow or practically arrested growth of the leader and the continued growth of the upper side branches forms a rounded top. Twigs of a season's growth are smooth, shiny, and yellowish-green, later becoming ashy or brownish-green. The scaly winter buds are from one-eighth to three-sixteenths of an inch in diameter and covered with resin.

The color of the foliage varies in different parts of the tree's range from a yellow-green (with distinct bluish cast when young) to pale yellow-green with whitish tinge. The newly-matured foliage of old trees is, however, often decidedly bluish for a season, but later becomes much paler. In general, trees of the southern Rockies are apt to have much bluer foliage than those grown farther north, while, as a rule, the foliage of Rocky Mountain trees is whiter or bluer than is the case with Pacific slope trees. The leaves are flat, plump, blunt, or pointed (usually not pointed on lower and middle-crown branches, but sometimes pointed on lower branches of old trees) and are crowded, apparently, on the upper sides of the twigs and branches (Pls. XX, XXI, and XXII). On the lower branches of young trees they are horizontally flat, straight, and stand out more or less distinctly from two sides of these branches by a twist at their bases (Pl. IX). Very commonly, however, the leaves of the lower branches of young trees, and nearly always of old trees, are curved upward and stand erect somewhat in two lines from the top side of the twigs (Pls. IX and XX). Leaves of the upper crown, especially on the topmost branches, are strongly curved or sickle-shaped and appear to grow from the upper sides of the branchlets (Pls. XXI and XXII). The leaves of upper branches and those on leaders are always sharp-pointed. Lower-branch leaves are usually from $1\frac{1}{3}$ to 3 inches long, while those of the upper branches are commonly from about 1 to $1\frac{1}{3}$ inches long. There is also great variation in the length, form, and thickness of the leaves of this fir in different parts of its wide range.¹ A cross-section of a leaf shows two resin ducts each one situated very near the corner of the section and on the lower side. Both surfaces

¹ The changes in form from straight, horizontally flattened leaves to vertically flattened ones, either straight or curved like a sickle blade, are curious and unexplained, except perhaps by the fact that the latter form may present less leaf surface to the direct rays of the sun, thus fitting the tree to better endure the hot, dry climate in which this form of foliage is most common. Some authors hold that white fir of the Rocky Mountains bears longer leaves, and more commonly pointed ones, than do trees of the Pacific forests. The writer has, however, seen white fir in the latter region with quite as long leaves, while blunt leaves are not infrequent on trees in the Rockies.

of the leaves bear lines of minute pores (stomata), which give a whitish or pale bluish tinge to the foliage.

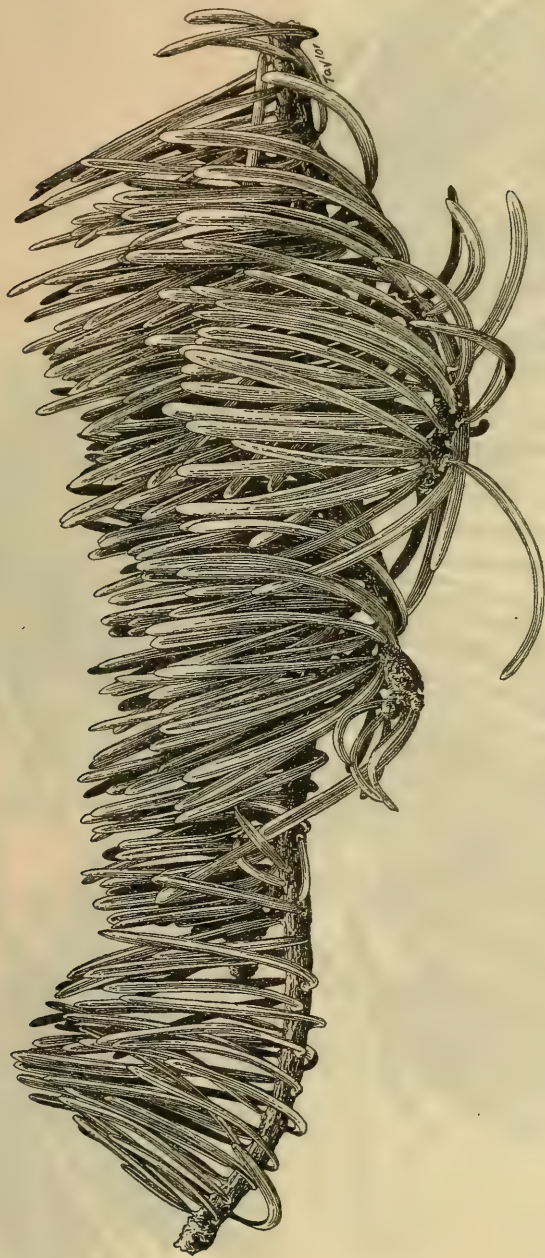
The cones (Pl. XXIII) are mature early in September, when they may be either very pale olive-green with an ashen tinge, or clear chrome-yellow green, while sometimes they are purple. They vary in length from about $3\frac{1}{4}$ to $4\frac{1}{4}$ (sometimes nearly 5) inches. The bracts, attached to the back of the cone-scales (Pl. XXIII, *a*), are sometimes rather narrow and oblong, or occasionally broad and rounded, the free end having a small, wide-based point extending from its center. The seeds (Pl. XXIII, *b*) are a dingy yellow-brown with shiny, clear, rose-tinted wings. The seed-leaves are commonly 6 in number, or occasionally 7.

White fir wood varies in color from whitish to a pale indistinct brown, being soft, rather wide-ringed, and straight-grained. In weight it ranks third among other Rocky Mountain firs, a cubic foot of dry wood weighing about $22\frac{1}{2}$ pounds. It works easily, and is strong and hard enough to be useful for saw timber, for which it is cut to some extent. Many large trees are, however, affected with "punk-rot" or are wind-shaken, defects which render much of the old stands useless for commercial purposes.

OCCURRENCE AND HABITS.

White fir is for the most part a tree of moderate altitudes, occurring in general at elevations between 6,000 and about 11,000 feet, but more frequently at altitudes between 7,000 and 9,000 feet. It usually grows on north slopes, and is especially abundant on benches and the sides of moist canyons of these aspects (Map No. 9). White fir is less particular as regards aspect in the North than in the South. It thrives in almost all fairly moist, well-drained soils, except heavy clays. The best growth, however, occurs in fairly deep, rich, moist gravelly or sandy loam soils. Frequently, nevertheless, it occurs on dry, nearly pure, coarse, disintegrated granite, and even among boulders, but it is of much smaller size in such situations. White fir requires less atmospheric and soil moisture than any of our other firs, yet its best growth is always in cool, moist situations.

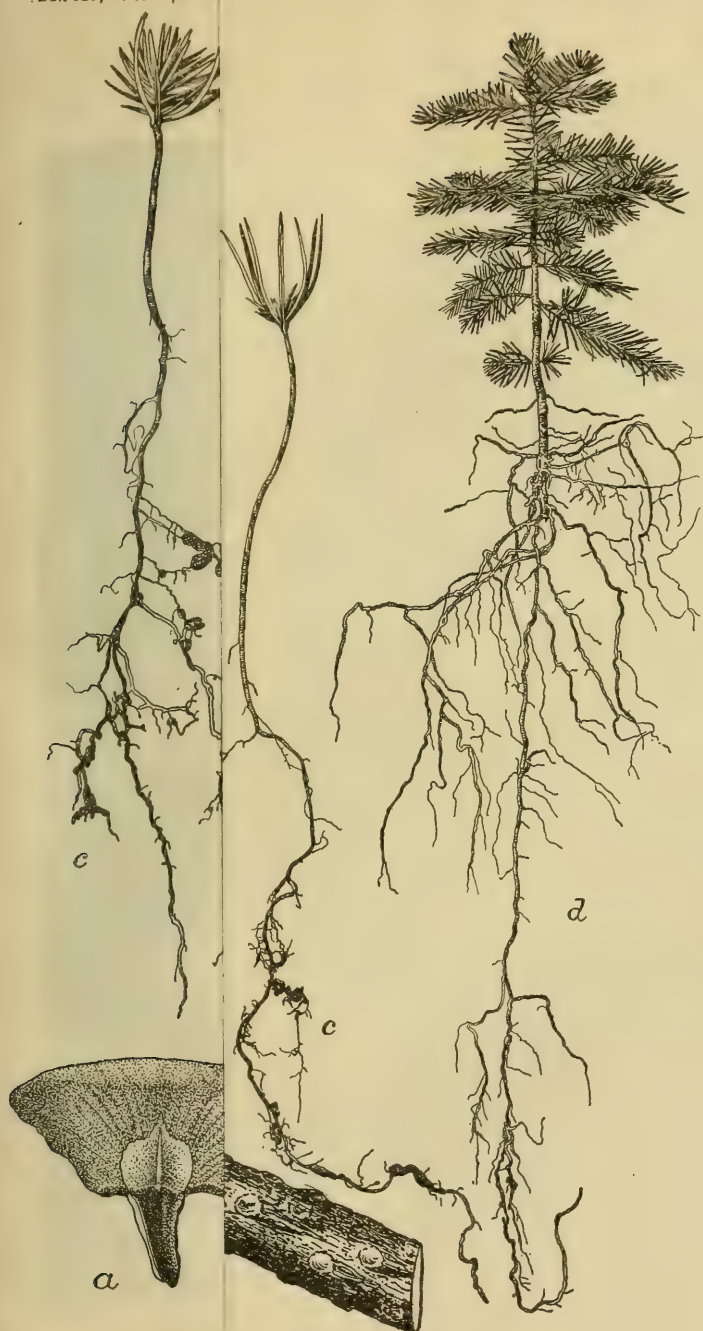
Abies concolor never forms pure stands of mature trees over large areas, although it occurs frequently in nearly pure growths of limited extent. Douglas fir is very commonly associated with white fir, and alpine fir, Engelmann spruce, and aspen are found with it more or less. Occasionally it occurs with western yellow pine and limber pine. The frequent dominant stands of young white fir, which occur mingled with Engelmann spruce or Douglas fir, usually give way in numbers to the latter species when the pole stage is reached, so that the white fir later constitutes a much smaller percentage of the maturer stand than it did at the beginning.



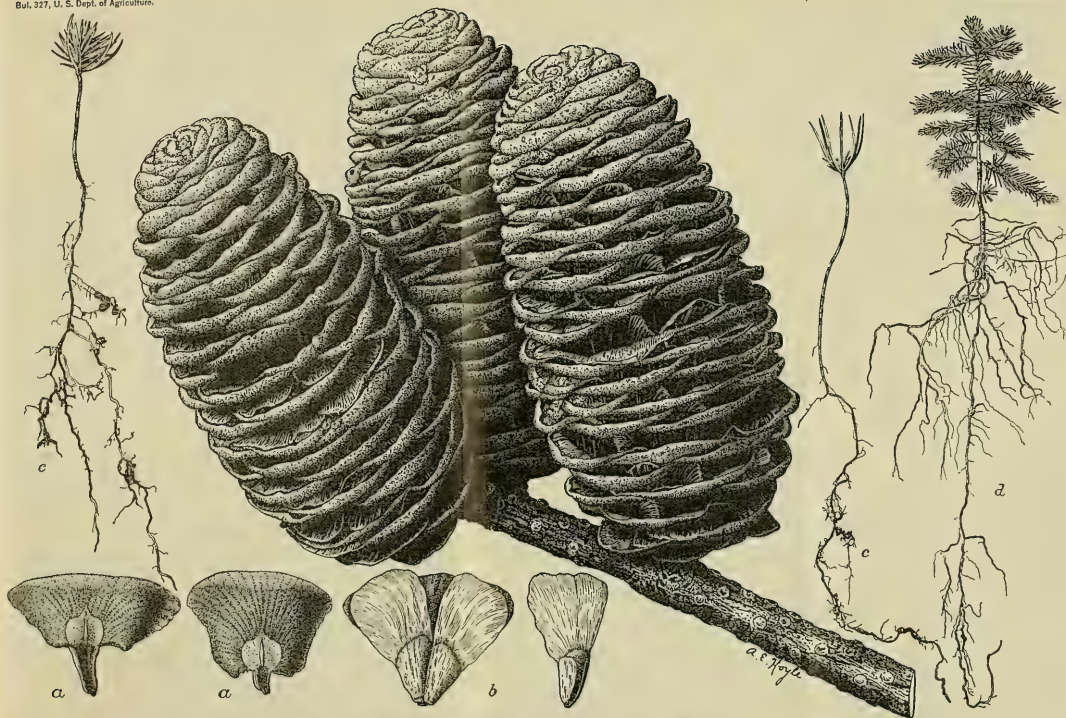
ABIES CONCOLOR: MIDDLE-CROWN BRANCH.



ABIES CONCOLOR: UPPER-CROWN BRANCH.



seedlings about two years old;



ABIES CONCOLOR: CLUSTER OF RIPE CONES; SCALES AND SEEDS NEARLY READY TO FALL FROM CENTRAL AXES.

a, Lower side of cone scales showing their bracts; b, upper side of cone scale with its winged seeds (as they are borne) and lower side of detached seed; c, seedlings about two years old; d, young trees seven years old (about one-half natural size).



ABIES CONCOLOR: TYPICAL THICK BARK OF TRUNK.



White fir is very tolerant of shade throughout its life, but it endures more shade from the seedling to the pole stage than at any other period. Such growths survive long suppression under heavy shade, but with slow progress, and recover readily when overhead light is admitted. White fir appears to be most tolerant of shade in moist soil, where usually it is able to endure more than any associated species except Engelmann spruce and alpine fir. Owing to its great tolerance, white fir has a closely branched crown, and the trunks lose their branches rather slowly.

White fir is a fairly prolific seeder, producing large crops of cones periodically. Good seed years occur only at irregular intervals of from two to four years, but some seed is produced nearly every year. As a rule, seed production begins mostly at a rather advanced age, but pole-size trees in dense stands may bear seed when their leaders reach full light. Seed bearing continues for many years, but it is more abundant during the period of rapid height growth (between the ages of 50 and 100 years) than at maturity. The seed has only a moderately high rate of germination (often under 40 per cent) and transient vitality. Reproduction is usually abundant, large dense groups of seedlings often resulting from a single tree's heavy seed crop.

The character of the seed bed is apparently of little importance, for seed germinates on moist, heavy litter and humus as well as in mineral soil. However, fairly abundant soil moisture is essential during the first few months following germination in order that the seedlings may become established. Indifference to the kind of seed bed renders this tree more than ordinarily aggressive, reproduction occurring over denuded lands adjacent to seed trees as well as immediately under their own shade.

Large quantities of seed of this fir are eaten by squirrels¹ and probably also by other rodents which doubtless avail themselves of

¹The remarkable sagacity of pine squirrels is shown by an incident observed by the writer in connection with their "cutting" of white fir cones in the Manzano National Forest, N. Mex. Part of the cones "cut" from a tree had necessarily fallen directly into a shallow pool of spring water beneath the tree, and it is equally certain that part of them fell on the border of the pool. The latter supply of cones had, however, evidently been dragged to the abrupt edge of the pool and pushed into the water. Altogether a bushel or more of cones were thus cached in the water. Evidence that the squirrels had deposited part of the cones in the water appeared in the fact that cones were especially numerous in the water at the edge of the pool. None were to be found anywhere on the ground about the pool. While the squirrels were not actually seen at work, the position of the tree with reference to the pool was such that only a part of the cones "cut down" could have fallen directly into the water, while the remainder clearly must have reached the ground. The writer was informed by a settler's lad who frequently passed the pool that he had seen the squirrels dragging cones to the water's edge. The effect of placing ripe fir cones in water is to prevent them from breaking up and liberating their seeds, which occurs when the cones are left on the ground exposed to the air. While it is believable that the placing of these cones in the water may have been in accordance with the instinct of squirrels and many other rodents to cache their winter supply of food, it seems quite unbelievable that the squirrels could know and profit by the fact that immersing fir cones in water temporarily preserves them intact.

the abundant supply of cones the squirrels "cut down." During light or poor seed years this consumption may in some localities well include practically the entire crop, but in seasons of heavy seed production, the loss from rodents must still allow abundant reproduction.

LONGEVITY.

In general white fir grows rapidly in height and diameter for the first 50 to 100 years, after which it grows slowly up to about 350 years, which is believed to be near its maximum age. The age limit of white fir in the Rocky Mountain region is not fully known at present, but very probably the largest trees are not over 250 or 275 years old.

SHASTA RED FIR.

Abies magnifica shastensis Lemmon.

COMMON NAME AND EARLY HISTORY.

The Shasta red fir has only a very limited range in the Rocky Mountain region (Map No. 10; western edge of Nevada), its principal range lying in the Pacific slope region.

From the forester's point of view *Abies magnifica* and its variety, *A. magnifica shastensis*, which is distinguished from the former by its shorter and thicker cones and by the exserted bract of its cone scales (Pl. XXV, *a*), are practically one tree. Indeed, without seeing the mature cones of the species and its variety, it is impossible to distinguish one tree from the other. Their silvical habits and habitat are essentially the same.

The common name, Shasta red fir, derived partly from the technical name, is probably not used by woodsmen and other laymen who generally call the species and variety "red fir." The name Shasta red fir refers appropriately to the deep red-brown bark which both the species and its variety invariably have throughout their range, and to the historical fact that the tree was originally found on Mount Shasta, Cal.

Abies magnifica was first discovered in 1845 by Col. Frémont on his expedition to California, the first authentic description of it appearing in 1863. The Shasta red fir was found first on Mount Shasta, Cal., in 1852 by the intrepid Scotch explorer John Jeffrey. The earliest technical name given to this form is probably "*Abies nobilis rubusta*" of Carrière, published in 1867; but it is impossible to be sure now that Carrière's accompanying description applies to the Shasta fir, which in 1890 was properly distinguished for the first time as "*Abies magnifica* var. *shastensis*" by Dr. J. G. Lemmon.

This author later believed it to be a distinct species, and in 1897 published the name "*Abies shastensis*." A long and careful field study of this tree has convinced the writer, however, that it is only a varietal form of *Abies magnifica*.

DISTINGUISHING CHARACTERISTICS.

Abies magnifica is a tree of stately dimensions, ranging from 125 to 175 feet in height, or very exceptionally 200 feet or more, and from 30 to 50 inches in diameter; trees from 60 to 80 inches in diameter are rather rare. Much larger trees are said to have been found, but the writer has never seen them. *Abies magnifica shastensis* occurs only at high elevations where conditions for growth are much less favorable than within the main vertical range of the species, so that it rarely exceeds 125 feet in height and 3 feet in diameter. In close stands at lower elevations the trunks of large trees are straight and slightly tapering. Smaller trees on high exposed slopes are often conspicuously and permanently bent down the slope at their base, as a result of heavy snows which yearly force the seedlings to the ground. Their later struggle to regain an upright position never wholly rids the trees of this basal bend in the trunk, which remains a mark of early vicissitudes.

The bark of young Shasta red fir trees is smooth and conspicuously chalky white, as it is also on the upper stem and branches of old trees, while on the lower trunks of older trees it is rough with deep furrows and narrow, rounded ridges. It varies in thickness from 2 to 3 inches according to the size of the tree. The main vertical ridges of the bark are irregularly divided by diagonal furrows, which give a peculiar zigzag appearance to the bark. Externally the rough bark of old trunks is a deep purplish-brown and a bright purple-brown within. No other fir tree in this region has bark similar in any particular to this.

The crown of old forest grown trees is a short, very narrow, round-topped cone, sometimes almost cylindrical. The short branches droop except at the top of the crown, where they trend upward. The crown is noticeably open, due to the fact that the circles or whorls of branches grow from the trunk at rather wide and regular intervals. Only in the densest stands are medium-size trees clear of branches for half or more of their length. In the high, fairly dense Pacific Slope forests many trees bear straggling branches nearly to the ground. At high elevations, too, the brittle tops are often broken off by wind, when the lost member is replaced by the upward growth of one or two side branches, which soon assume the form and place of leaders. Broken and repaired crowns of this type are familiar sights on wind-swept slopes inhabited by this fir. Young

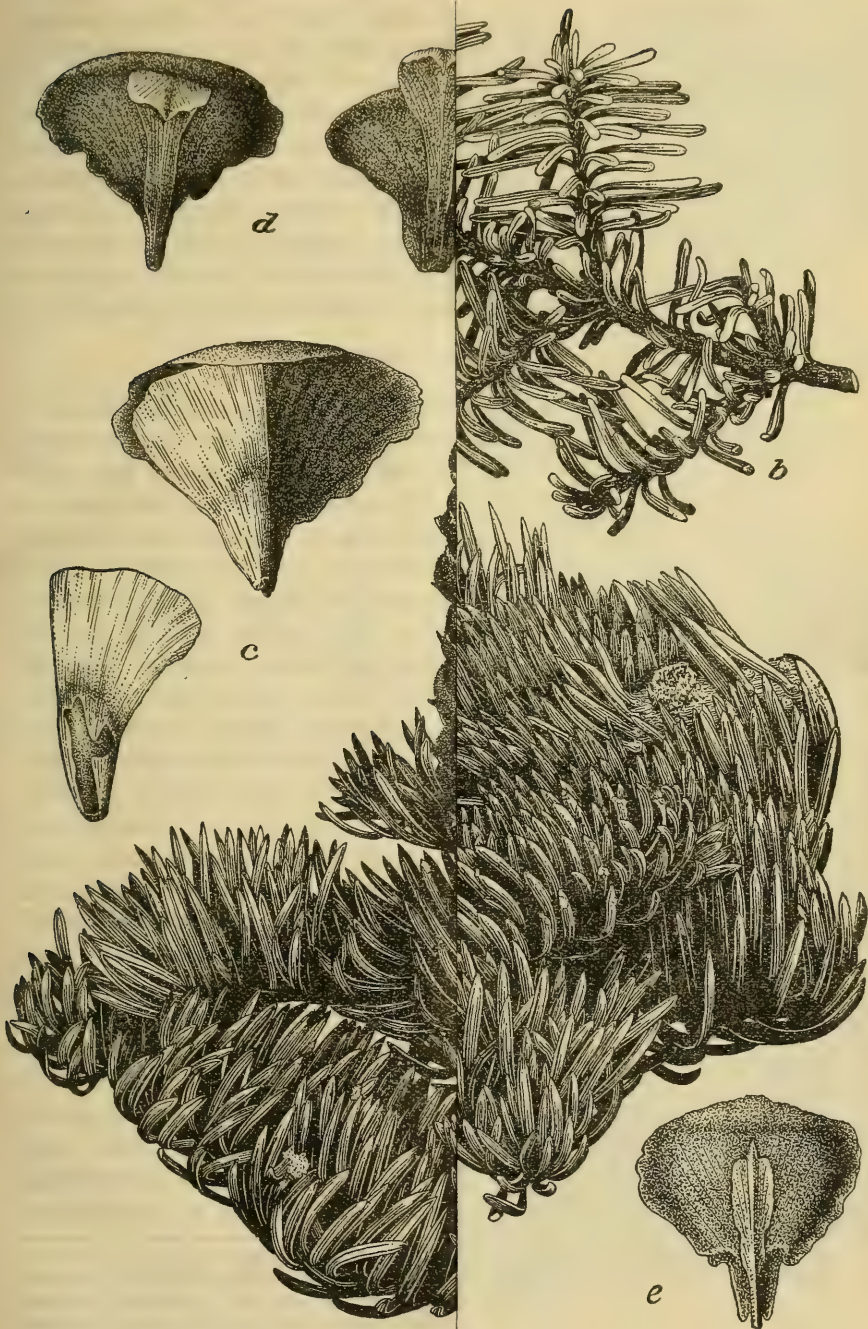
trees (30 to 50 years old and as many feet high) have narrow, cylindrical, sharp-pointed crowns, extending down to the ground. All of the regular groups of branches, except the topmost, sweep down and upward at their ends in graceful curves, presenting a form which is unsurpassed in beauty and symmetry by any of our other conifers.

The sharp-pointed winter buds are light chocolate-brown and about one-fourth of an inch long. Unlike the winter buds of other firs of this region, those of the Shasta fir are not resinous.

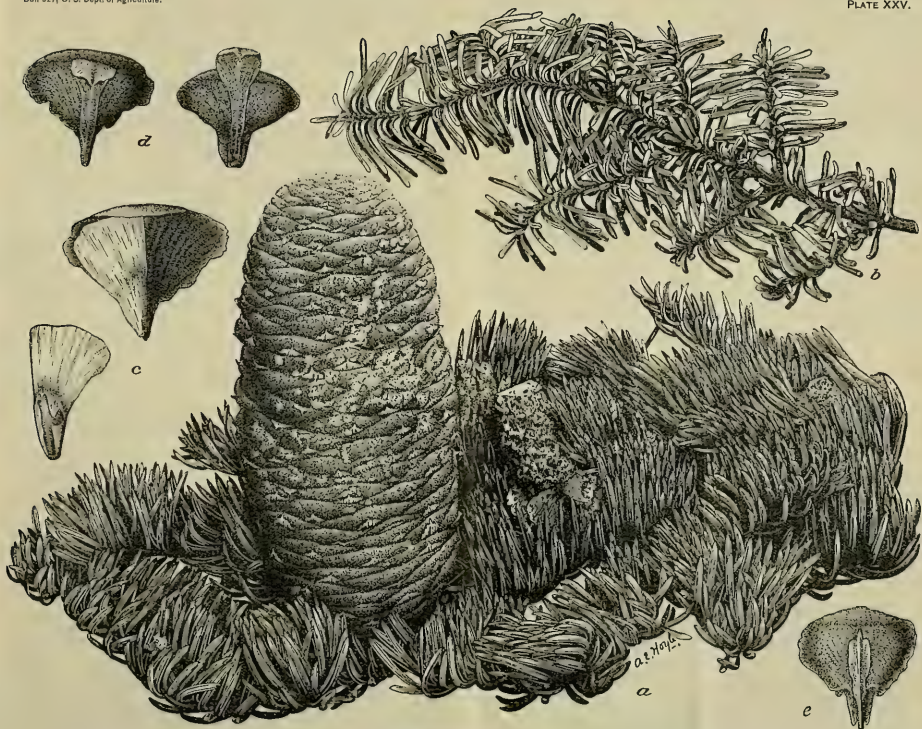
The dense foliage is dark blue-green, with a whitish tinge; new leaves, produced each season, are at first a much lighter green and more conspicuously whitened than when older. The leaves are four-angled, with nearly equal sides, the angle on the upper sides of the leaves being rounded. Leaves of the lower branches (Pl. XXV, *b*) are flatter than those on other parts of the crown (Pl. XXV, *a*). Those on the lower side of the branches are so bent that they appear to grow from the top side of the branch, and mainly in two dense upright lines. All of the leaves are, however, more or less curved. The leaves of lower branches are from three-fourths of an inch to about $1\frac{1}{4}$ inches long, blunt or rounded at the end, and wider there than at the base. Leaves of the upper-crown branches (Pl. XXV, *a*) are more strongly four-sided and stouter than those of lower branches and are conspicuously curved and densely crowded toward and on the top of the branches. They are from five-eighths of an inch to about $1\frac{1}{8}$ inches long and more or less distinctly pointed; leaves of the leader are also somewhat sharply pointed and incurved to the stem.

The cones (Pl. XXV, *a*) are mature by the middle or end of August, and during September they break up and liberate the seeds (Pl. XXV, *c*). At maturity they are deep purple in color and often tinged with brown. They vary in length from about $4\frac{1}{2}$ to $5\frac{1}{2}$ inches by about $2\frac{1}{2}$ to 3 inches in diameter and in form from cylindrical to a long egg shape. The bracts, attached to the backs of the cone scales, are always broad at the end and in some cases scarcely or only slightly extended beyond the ends of the cone scales (Pl. XXV, *a*), while in others the bracts may be conspicuously extended (Pl. XXV, *d*).¹ The large-winged seeds (Pl. XXV, *c*) are dark brown, with shiny, purplish or rose-colored wings. The seed-leaves vary from 9 to 13, but are usually 12, and are about five-eighths of an inch long and bluntly pointed.

¹ Shasta red fir trees have been found bearing some cones with plainly exerted bracts and others with bracts entirely hidden. The hidden and exerted bracts do not differ essentially in form. In 1899 the writer found a group of trees at "Alta Meadows" (Sequoia National Park, Cal.), on some of which all of the cones bore exerted bracts, while on other trees the cones bore only hidden bracts. There is a sharp distinction between the form of the bract produced by *Abies magnifica* and its variety *shastensis*, bracts of the latter being broadly rounded at the end (Pl. XXV, *d*) and bracts of the species being narrowly lance pointed (Pl. XXV, *e*). No forms of bracts strictly intermediate between these extreme types have as yet been discovered.



a, Upper-crown branch and ripe cone; b, led; d, lower side of cone scales showing large *ica*.



ABIES MAGNIFICA SHASTENSIS.

a, Upper-crown branch and ripe cone; *b*, lower-crown branch; *c*, upper side of cone scale with one of its winged seeds and lower side detached seed; *d*, lower side of cone scales showing large form of protruding bracts; *e*, lower side of cone scale showing smaller and shorter bract of *Abies magnifica*.

The wood of Shasta red fir is the heaviest of all the firs in this region, a cubic foot of dry wood weighing about 29 pounds. It is yellowish-brown in color with a reddish tinge, straight-grained, usually narrow-ringed, and of a soft but firm texture. The wood of old trees is rather brittle. In an unprotected state the seasoned wood is considerably more durable than that of any other native fir. The commercial value of the better grades of this wood is yet to be determined. When other timber of lower elevations becomes scarcer the firmness and good working qualities of Shasta red fir wood are likely to render it useful for a number of the purposes to which pine is put. At present the tree is not cut for commercial purposes.

OCCURRENCE AND HABITS.

Shasta red fir is essentially a tree of high mountain habitat, sometimes well up to timber line. It occurs generally at elevations between 5,500 and about 10,000 feet, the higher elevation being reached in our southern Sierras. Within the Rocky Mountain region it occurs chiefly at elevations from about 6,000 to 8,000 feet, the main growth lying between 6,800 and 7,500 feet (Map No. 10).¹ It grows both on protected, gentle mountain slopes about meadows, in cool, sheltered ravines, gulches, and on high rolling mountain plateaus, as well as on steep, exposed, wind-swept mountain sides near high divides and crests. Shasta red fir prefers north and east exposures, where it is confined mostly to the available moist, cool sites. It is much less frequent on drier and warmer southern exposures in the former locations. The tree grows most abundantly and to the largest size, in moist, porous, sandy or gravelly loam soils; but it is found also in very rocky, poor situations with little available soil. Poverty of soil and moisture in such places, however, produces small or stunted trees. Under favorable conditions for growth Shasta red fir forms large pure stands and also nearly pure stands, the latter being interspersed more or less with scattered growths of lodgepole pine, western white pine, and white fir.

Shasta red fir is only moderately tolerant of shade at any period of its life, full enjoyment of sunlight being required for the best development. It is much less tolerant of shade than white fir, incense cedar, and Douglas fir, but very similar to noble fir in its requirement of light. Rarely to any extent does Shasta red fir grow in intermediate or subordinate positions, but nearly always in stands

¹ The exact range of Shasta red fir has not been fully worked out. Following its first detection on Mount Shasta, California, it was found on the coast and cross ranges of northern California, and also on the Cascade Mountains of Oregon. Later it was observed by the writer on the divides of Kaweah River watersheds and elsewhere far south of Mount Shasta, in the southern Sierras, while still later it was found to be abundant on Washoe Mountain in northwestern Nevada.

of equal age, which favor overhead light to all of the trees. It endures but little side shade, as is shown by the long, clean trunks it produces in close stands and commonly also even in rather open stands. Ability to endure shade, however, appears to vary with the nature of the soil, available moisture, and climatic conditions, trees always showing relatively greater tolerance of shade under the best conditions for growth.

Shasta red fir seeds plentifully, good crops of cones being produced about every two or three years. Seed production is usually greatest in the more open stands of moderately old trees. The seed has a fairly high rate of germination, but under ordinary conditions of storage its vitality is retained for only a few months. Germination occurs abundantly on moist mineral soil in the open or under light shade, being much less frequent or wanting on dry, thick duff. Seedlings grow rapidly in cool, moist, sandy soil, soon restocking high slopes and openings cleared by fire or storm.

LONGEVITY.

Shasta red fir appears to be rather long lived. Trees from 20 to 36 inches in diameter are from 225 to 370 years old. Very large trees, not yet studied chiefly because the timber is not now cut for milling, would certainly show much greater ages. There are evident differences, not yet determined, in the longevity of trees growing on high, exposed slopes and those at lower levels in more protected places, trees of higher elevations naturally being considerably older than those of the same diameter growing at lower levels.

KEY TO GENERA.

Leaves four sided; cones hanging down or curved downward, the cone scales firmly attached and not falling away when the cones are ripe. *Picea*.
 Leaves flat, grooved on the upper side; cones upright, the cone scales easily detachable and falling away from a persistent spikelike central stem when the cones are ripe. *Abies*.

KEY TO PICEA.

Twigs smooth:

Leaves very keenly pointed and stiff; cones mostly 3 to 4 inches long. *Picea parryana*.

Leaves only moderately sharp-pointed; cones mostly 1½ to 2½ inches long. *Picea canadensis*.

Twigs minutely hairy:

Cones firmly attached to the twigs and persistent for a number of years. *Picea mariana*.

Cones lightly attached to the twigs and soon falling from the trees. *Picea engelmanni*.

KEY TO ABIES.

- Leaves of lowest branches arranged in two ranks (on two sides of the twigs) and mostly notched at the end----- *Abies grandis*.
 Leaves of lower branches more or less densely crowded on the upper sides of the twigs and with no notch at the end:
 Bark of the trunk soft and corky----- *Abies arizonica*.
 Bark of the trunk hard and tough:
 (1) Irregularly and shallowly seamed----- *Abies lasiocarpa*.
 (2) More or less regularly and deeply furrowed and ridged:
 (a) Externally dark reddish-brown----- *A. magnifica shastensis*.
 (b) Externally ashy-gray----- *Abies concolor*.
 Bark of the trunk scaly, the small scales easily detached-- *Abies balsamea*.

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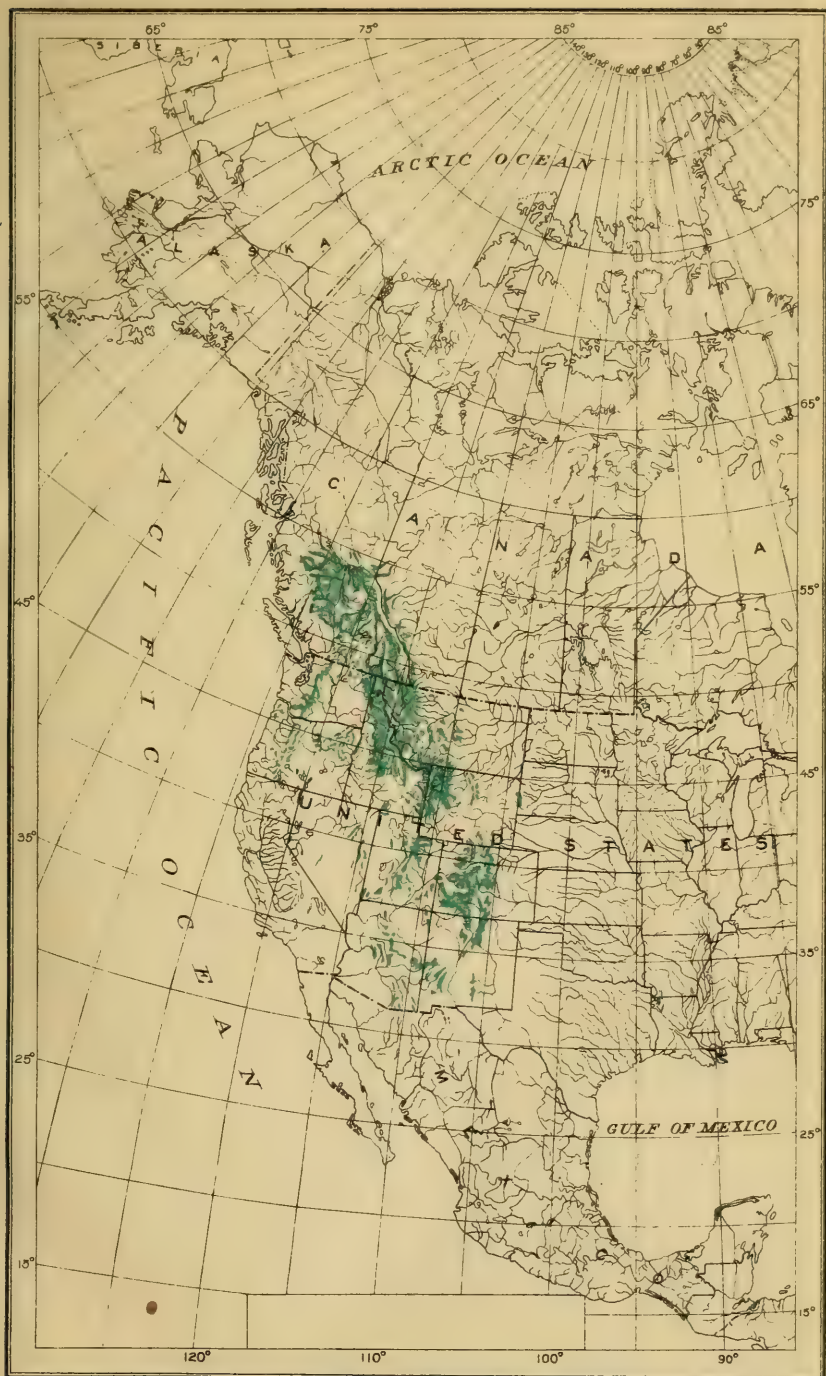
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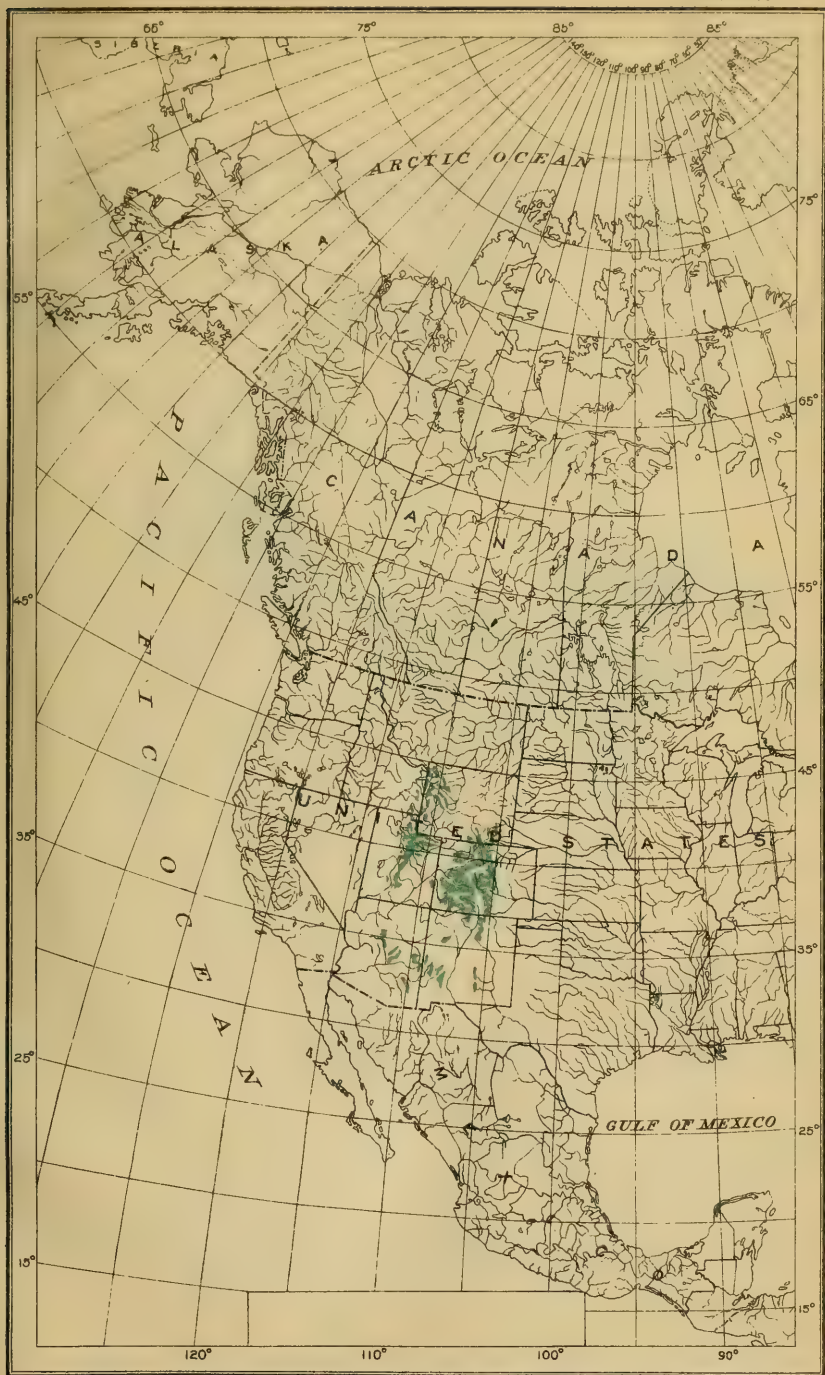


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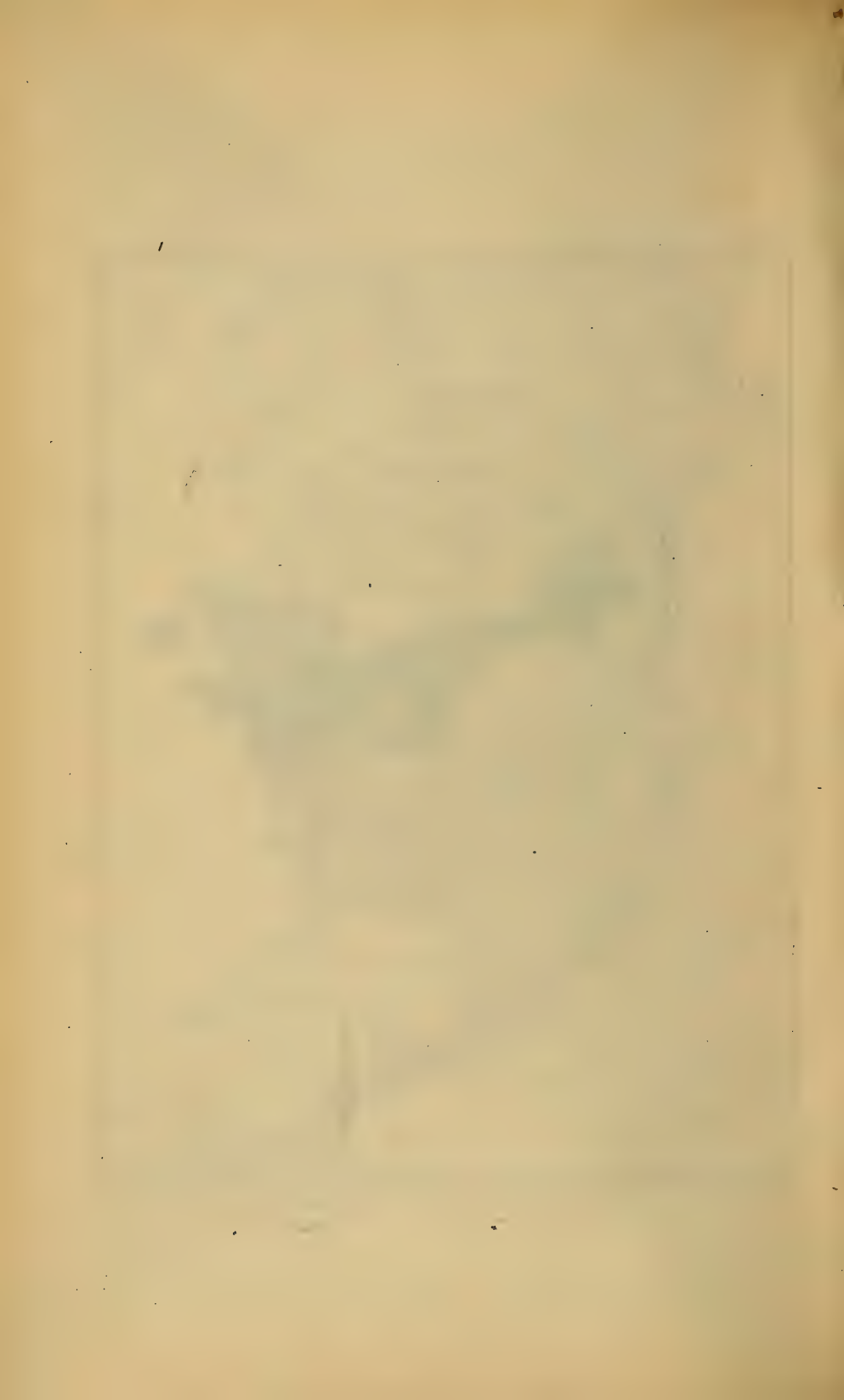


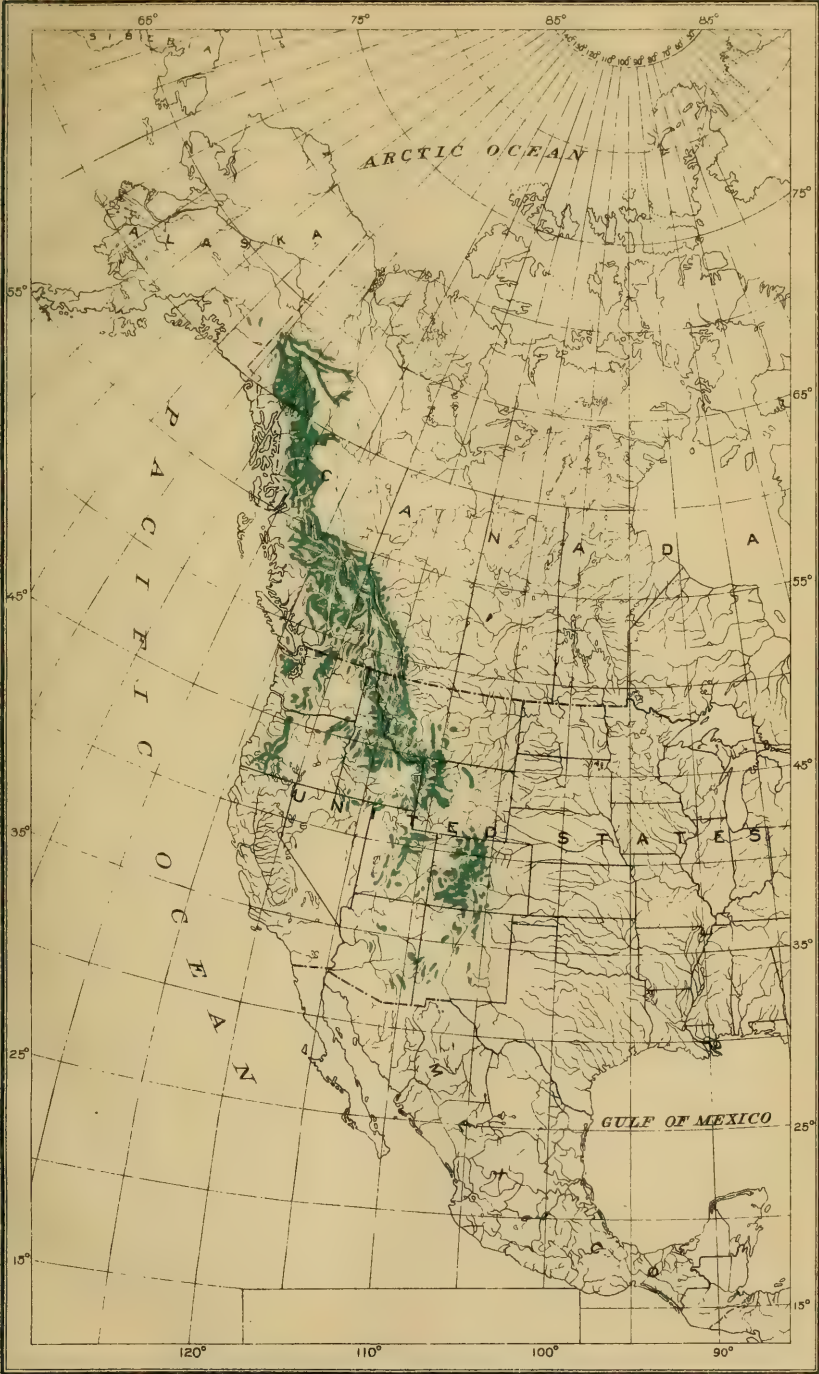


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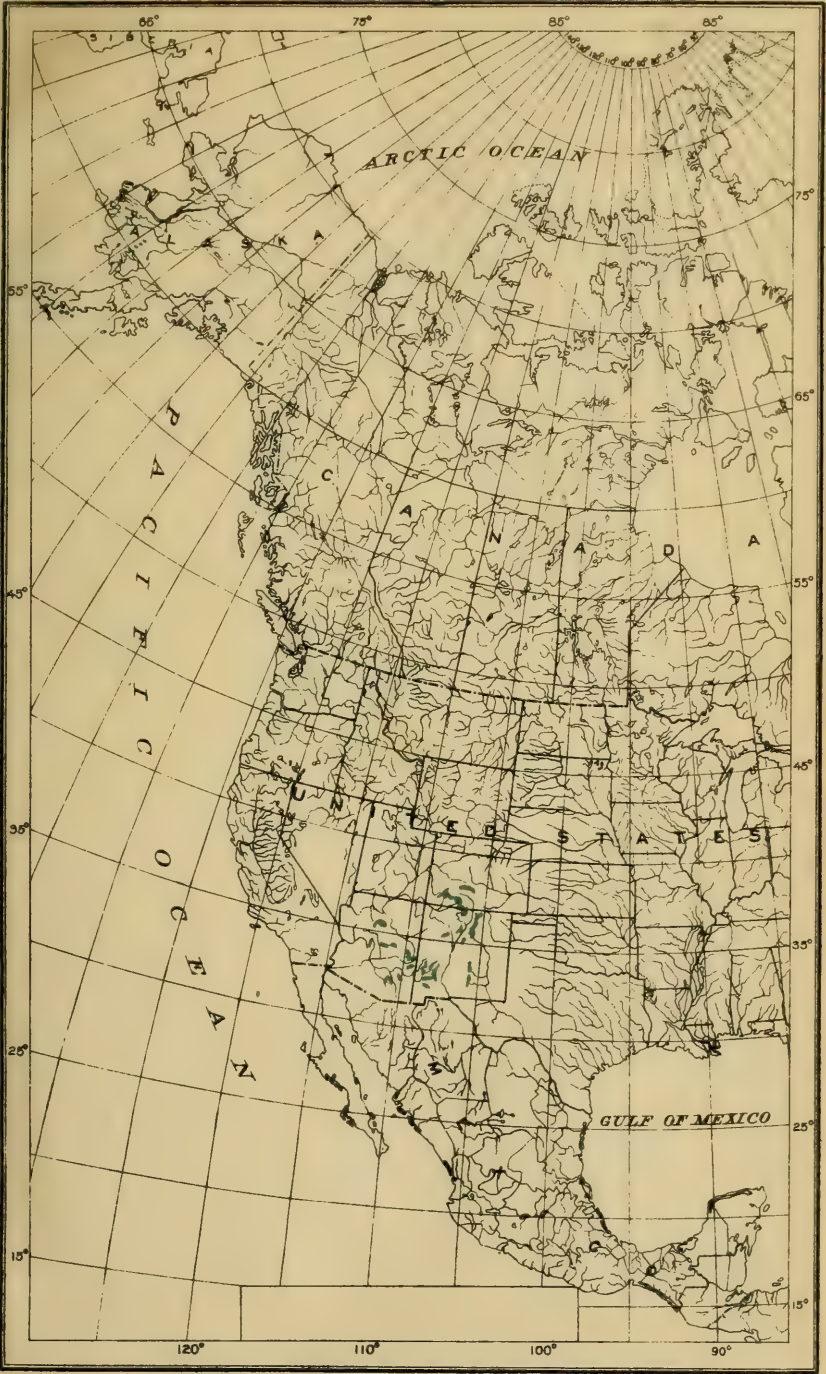
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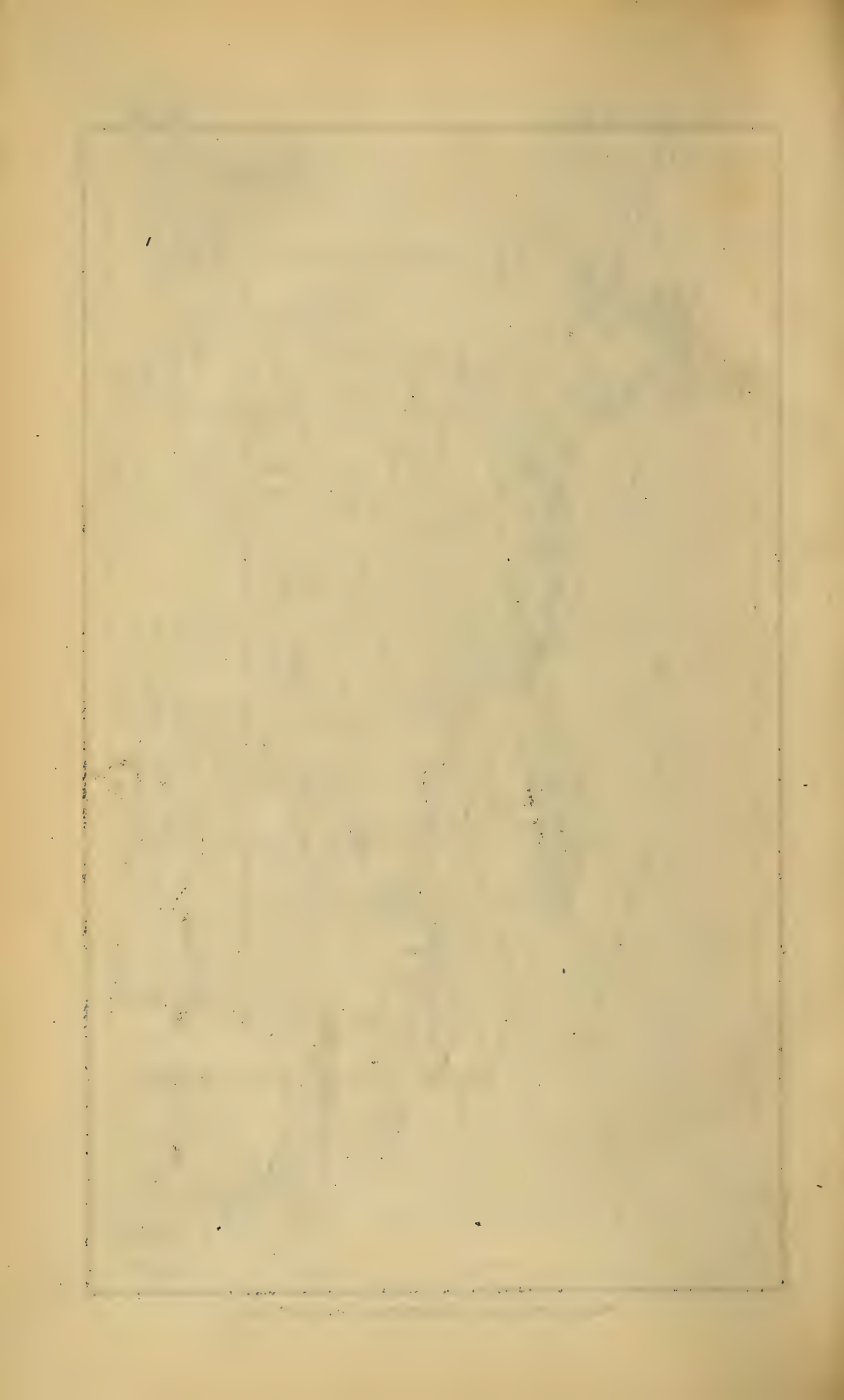


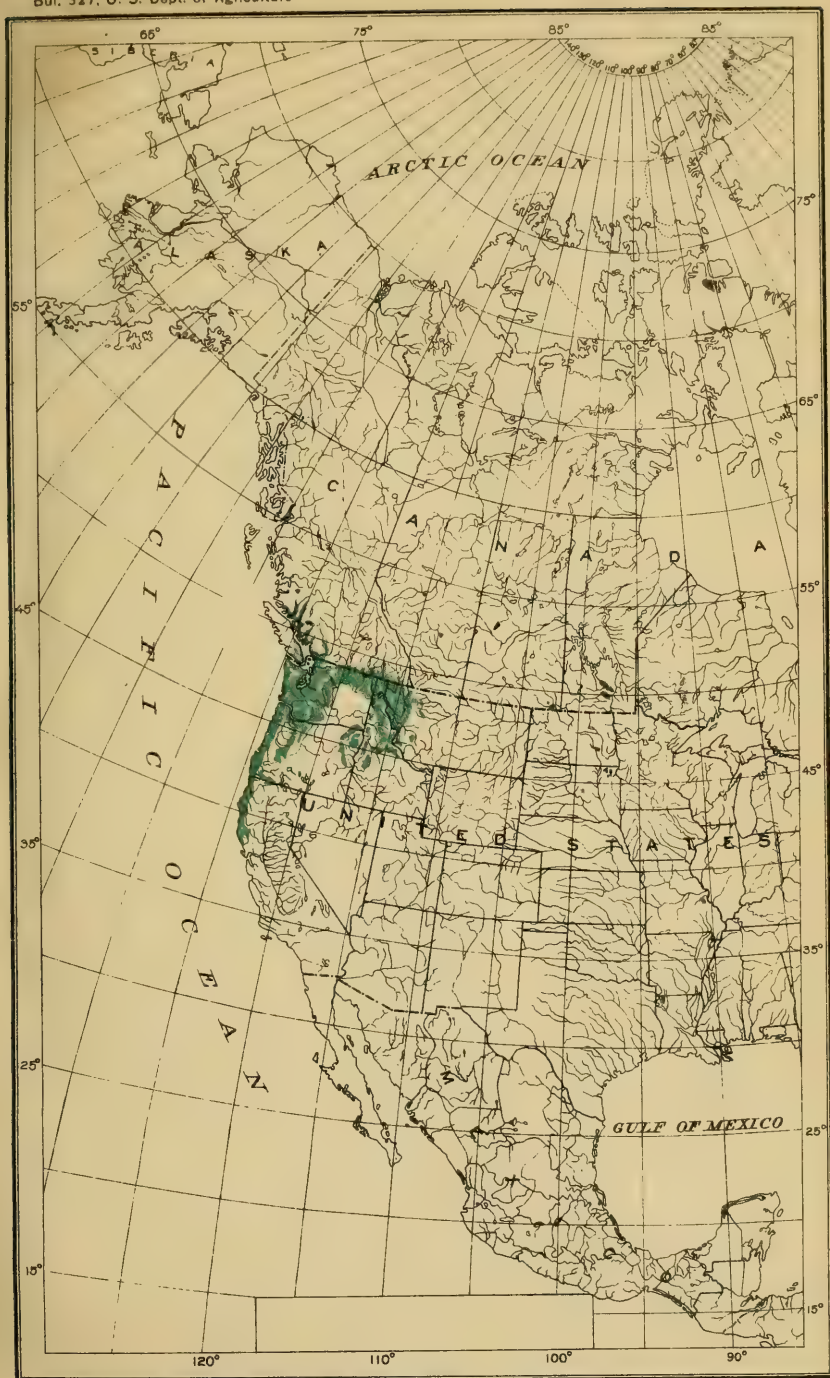
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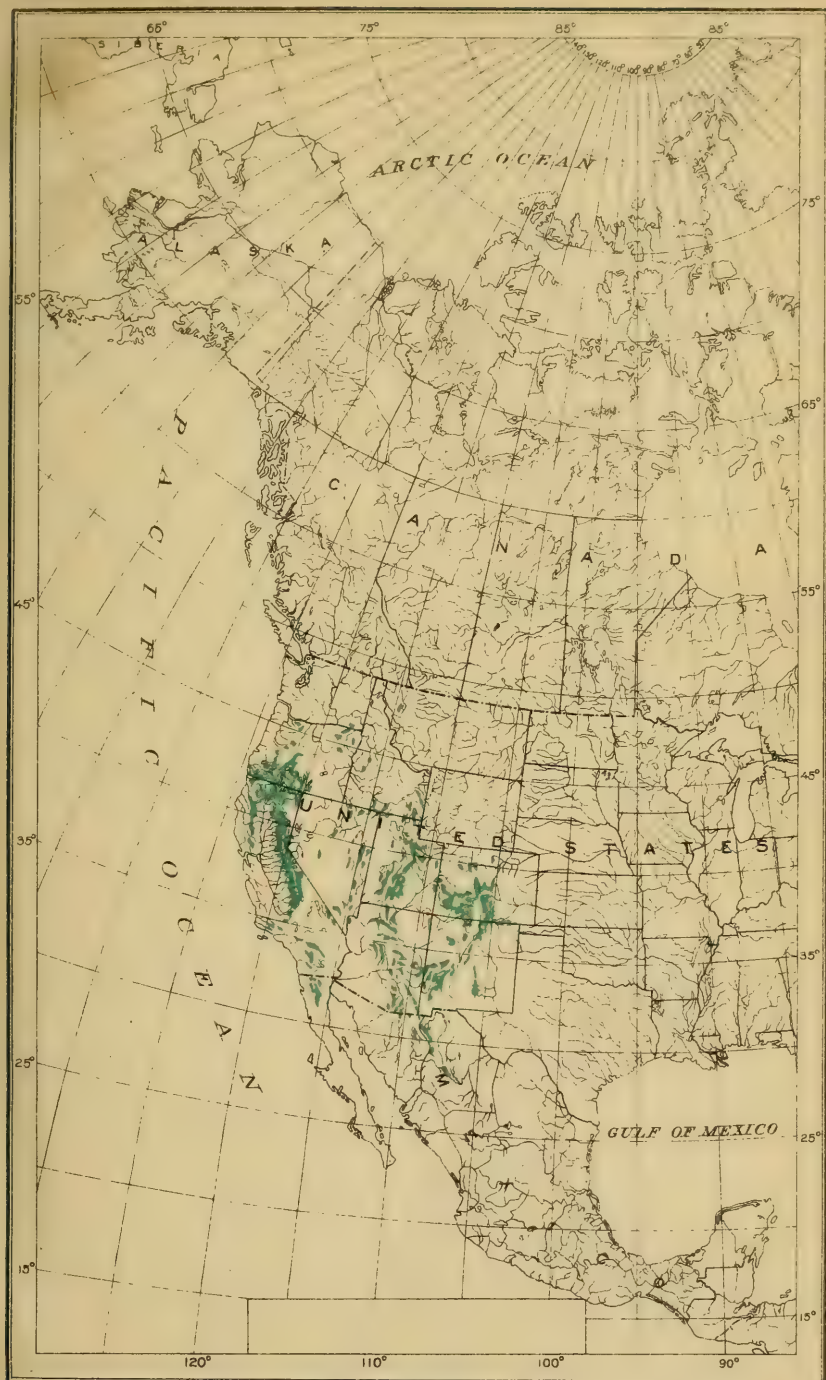


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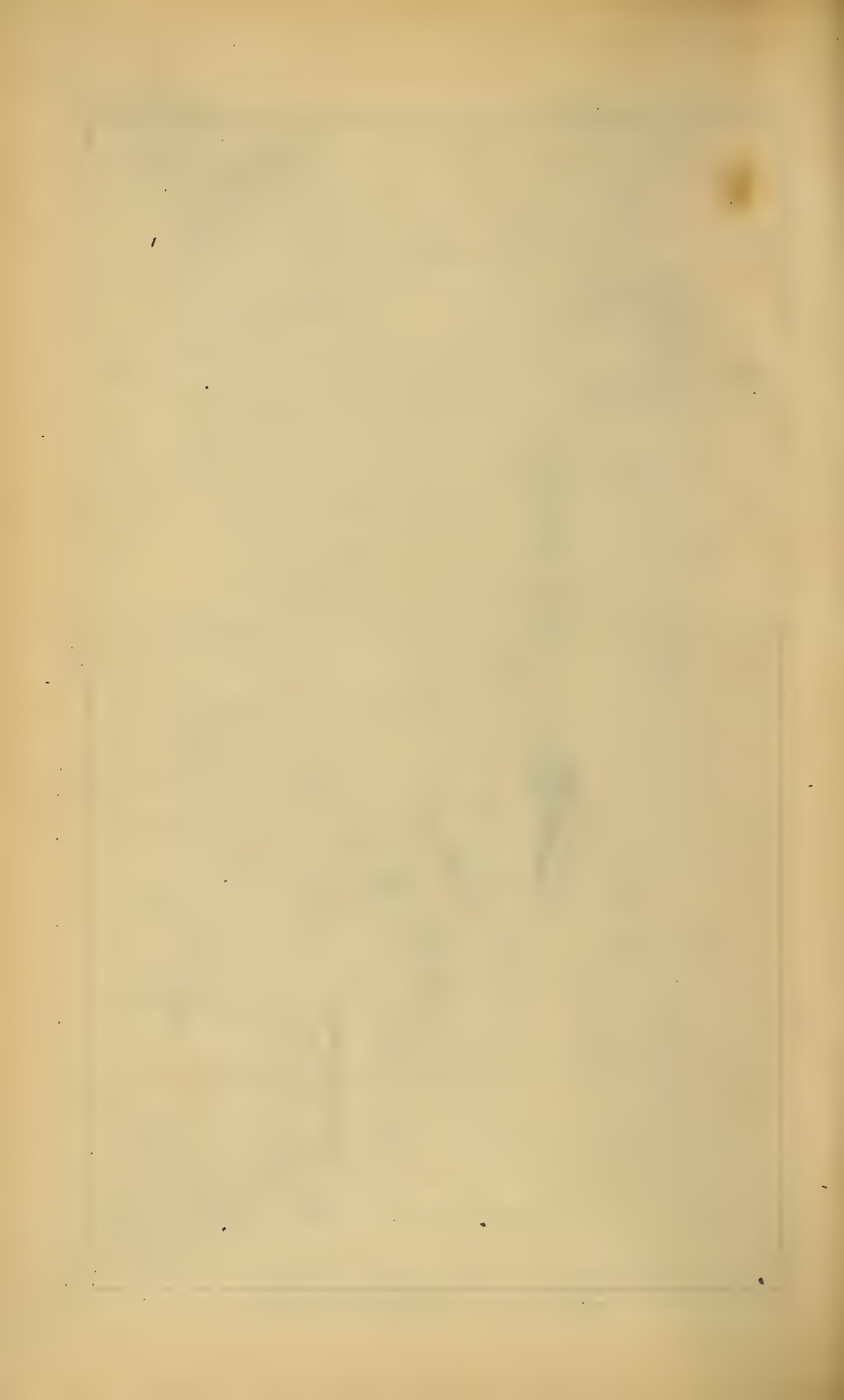


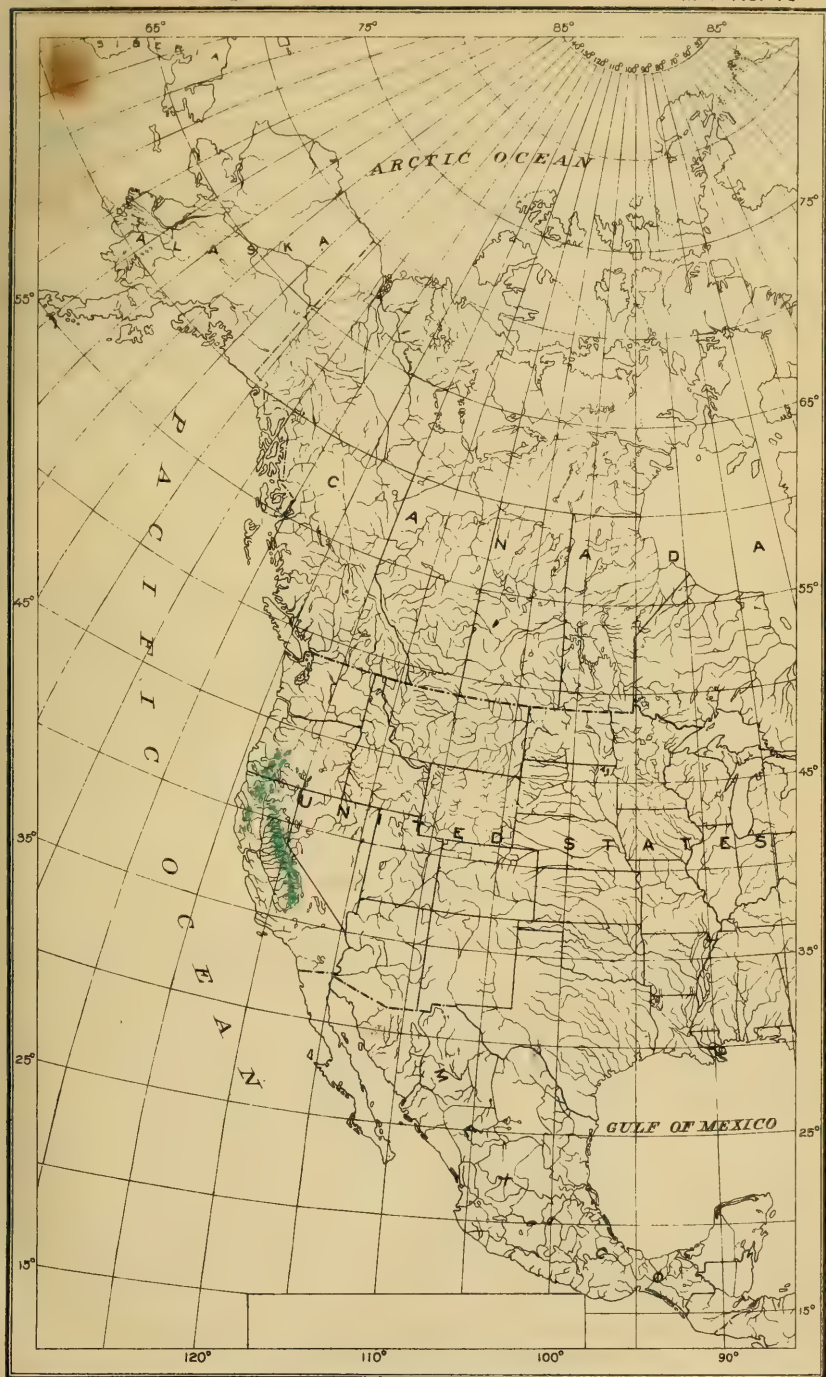


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UNITED STATES DEPARTMENT OF AGRICULTURE



BULLETIN No. 328

Contribution from the Bureau of Plant Industry
WM. A. TAYLOR, Chief



Washington, D. C.

PROFESSIONAL PAPER

December 30, 1915

MILLING AND BAKING TESTS OF WHEAT CONTAINING ADMIXTURES OF RYE, CORN COCKLE, KINGHEAD, AND VETCH.

By R. C. MILLER, *Assistant in Charge of Dockage Investigations, Office of Grain Standardization.*

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INTRODUCTION.

Wheat as grown and as marketed frequently contains various kinds of so-called inseparable impurities, such as rye (*Secale cereale*), corn cockle (*Agrostemma githago*), kinghead, or great ragweed (*Ambrosia trifida*), and wild vetch (*Vicia angustifolia*). These impurities are considered inseparable, inasmuch as they are not readily removed from wheat by the grain-cleaning machinery in general use in grain elevators and flour mills, because of their similarity in size, shape, and specific gravity to the wheat in which they occur.

Millers claim that the presence of these impurities in wheat in appreciable amounts injures the milling and baking qualities of the flour. The result is that wheat which contains a noticeable amount of these ingredients when marketed is generally penalized by being

NOTE.—The data presented in this bulletin are applicable to the wheat-producing sections of the United States and are of interest to farmers, grain dealers, flour millers, and bakers.

given a lower commercial grade or by a reduction in price, as compared with wheat that is free from such impurities. Special experiments to determine the effects that these impurities have on the milling and baking qualities of wheat were begun in 1912 by the Office of Grain Standardization and were continued in 1913 and 1914.

The results of milling and baking experiments with wheat containing various amounts of rye, corn cockle, kinghead, and vetch show conclusively that these impurities have detrimental effects on the quality of the flour.¹ Further experiments are planned with such impurities as rye, barley, wild oats, kafir, and wild-rose seed, and also with sprouted and bin-burnt wheat.

FREQUENCY OF OCCURRENCE OF IMPURITIES IN WHEAT.

A study of the analyses of samples of wheat secured from the crops of 1911, 1912, and 1913, as grown and as marketed, shows that a large percentage of the samples of spring and durum wheat contained rye, barley, oats, wild oats, corn cockle, kinghead, and wild-rose seed, and that wild vetch is sometimes found in appreciable amounts. Rye was found in 83.1 per cent of the hard winter-wheat samples secured. This information is given in Table I.

TABLE I.—*Wheat samples from the crops of 1911, 1912, and 1913, which contained certain impurities, showing the percentage of each impurity found.*

Impurities found.	Spring and durum wheat (633 samples).				Hard winter wheat (267 samples).			
	Sam- ples con- tain- ing impu- rities.	Per- cent- age of total.	Percentage of impurity.		Sam- ples con- tain- ing impu- rities.	Per- cent- age of total.	Percentage of impurity.	
			Aver- age.	Maxi- mum.			Aver- age.	Maxi- mum.
Barley.....	453	71.6	0.23	12.9	5	1.87	Trace.	0.1
Rye.....	249	39.2	.06	14.3	222	83.1	0.31	4.1
Oats.....	590	93.2	.33	6.8	63	23.6	.03	3.3
Wild oats.....	562	88.8	1.36	28.5	0	0	0	0
Corn cockle.....	375	59.2	.11	6.0	0	0	0	0
Kinghead.....	124	19.8	.09	3.8	0	0	0	0
Wild vetch.....	42	6.8	.10	3.8	0	0	0	0
Wild rose.....	209	33.0	Trace.	.8	15	5.6	Trace.	.1

COMPARISON OF THE SPECIFIC GRAVITY OF WHEAT AND OF ITS IMPURITIES.

The specific gravity of wheat varies with the type or class and also with the quality. The average specific gravity of a number of samples of soft wheat, determined in connection with investigations with grain, was 1.3891, with a range between 1.3616 and 1.4133,

¹ The writer is indebted to Levi M. Thomas, assistant in charge of the milling and baking investigation of the Office of Grain Standardization, who made all the baking and practical tests with the flour, assisted by W. K. Marshall, aid in grain standardization, and to Thomas Sanderson, in charge of the experimental mill of the North Dakota Agricultural College, who made the milling tests.

while the average specific gravity of a number of samples of hard wheat was 1.4273, the range being from 1.4152 to 1.4427.

Roberts¹ found a range in specific gravity between 1.227 and 1.386 in tests with 52 different types of wheat.

In his studies of various kinds of seeds Nobbe² gives the average specific gravity of 30 samples of wheat as 1.4131, with a variation between 1.3766 and 1.4396. The specific gravity of various other seeds is also given, viz, corn cockle (*Agrostemma githago*), 1.233; rye, for different tests, 1.325 and 1.371; barley, 1.351. The specific gravity of different species of vetch (*Vicia*) is given as follows: *Vicia benghalensis*, 1.344; *Vicia dumetorum*, 1.203; *Vicia faba*, 1.298; *Vicia lutea*, 1.273; *Vicia monanthos*, 1.327; *Vicia narbonensis*, 1.300.

Table II gives a comparison of the specific gravity of wheat with the specific gravity of several impurities very frequently found in wheat. These figures represent but one test of the impurities used in the milling and baking tests described in the following pages. It will be noted that the corn-cockle seed has a specific gravity nearly equal to that of wheat, while rye and hairy vetch have a greater specific gravity than wheat. The samples of rye, barley, kafir, and hairy vetch were cleaned with a small milling separator to remove any foreign matter, such as chaff or dirt, and the small and light kernels were also removed. The samples of rye and hairy vetch were possibly above the average quality. This is indicated by the test weight per bushel after the samples were cleaned. The rye weighed 58 pounds and the hairy vetch 64 pounds per bushel in comparison with 57 pounds per bushel, the test weight of the wheat used in the various tests with the different impurities. The kinghead seed, though having a smaller specific gravity than wheat, is somewhat larger and is not readily removed with ordinary mill cleaning machinery.

TABLE II.—*Specific gravity of wheat and of certain impurities frequently found.*

Wheat and impurity.	Sp. gr.	Impurity.	Sp. gr.	Impurity.	Sp. gr.	Impurity.	Sp. gr.
Wheat (spring).....	1. 3992	Barley.....	1. 3425	Kafir.....	1. 3175	Corn cockle.....	1. 3915
Rye.....	1. 4097	Wild oats.....	1. 3320	Kinghead.....	. 9563	Hairy vetch.....	1. 4888

Figure 1 shows the comparative size and shape of wheat and rye kernels and of seeds of corn cockle, hairy vetch, kinghead, and wild vetch.

METHODS OF PREPARATION AND MILLING.

To insure greater uniformity in the different tests, a sufficient quantity of wheat of one variety was purchased each year to make all the milling tests desired. Thus, the samples milled and used as

¹ Roberts, H. F. Breeding for type of kernel in wheat. Kans. Agr. Exp. Sta. Bul. 170, p. 108-114, 1910.

² Noble, Friedrich. Handbuch der Samenkunde, p. 315-319. Berlin, 1876.

checks in each experiment are comparable with the samples containing the different impurities.

The wheat used in the experiment was thoroughly cleaned and scoured before making up the milling samples containing the various admixtures of rye, corn cockle, kinghead, and hairy vetch. This was done because the samples were neither cleaned nor scoured after the mixing, since it was desired that a definite known percentage of any added impurity should go to the rolls for milling into flour, bran, and shorts.

Each sample milled consisted of 100 pounds, including the impurity (e. g., 99 pounds of wheat and 1 pound of corn-cockle seed; 98 pounds of wheat and 2 pounds of corn cockle seed, etc.). The samples were

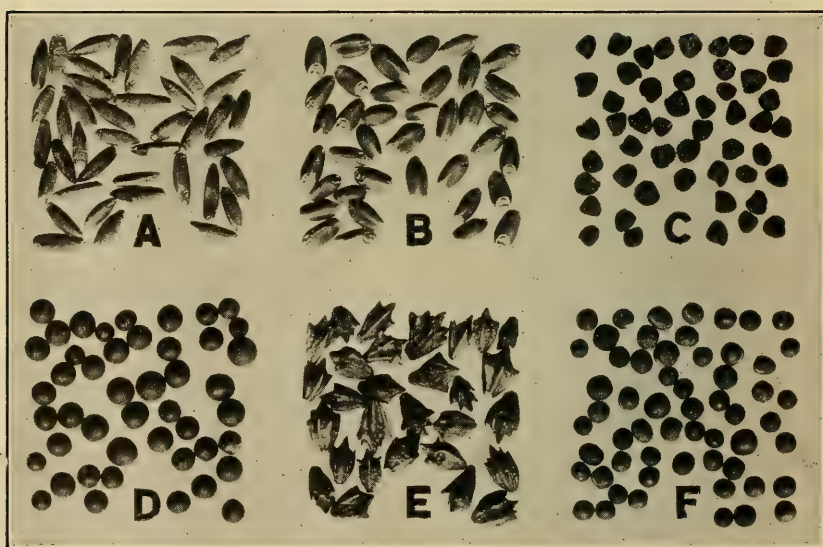


FIG. 1.—Grains of rye (A) and wheat (B); seeds of corn cockle (C), hairy vetch (D), kinghead (E), and wild vetch (F). On account of the shape, size, and specific gravity of these impurities they are not easily separated from wheat. (Natural size.)

milled at the North Dakota Agricultural College in the experimental mill, which has a capacity of 50 barrels per day of 24 hours.

To obtain results which would be comparable with average commercial conditions at country points, the methods of milling used in country mills were followed in general in the tests with the so-called inseparable impurities. The flour yields obtained compare very favorably with those secured by well-equipped country mills of 50 to 100 barrels daily capacity, since it was possible in milling the samples to make five breaks and as many reductions as desired, up to seven or eight.

In the tests covering the three years, the samples were milled as straight flours (that is, only one grade of flour was made from the

total flour obtained) and, in addition, in the 1913 tests, three grades of flour, viz, patent, first clear, and second clear, were made from wheat containing 10 per cent admixtures of rye, corn cockle, king-head, and hairy vetch, in order to study the effects of a large percentage of these different impurities on each grade of flour.

In the 1912 and 1913 tests where the one grade (straight flour) was made, the percentages of impurities used in the admixtures were 1, 2, 3, 5, and 10, except that in the 1912 experiment with corn cockle tests were made with but 1, 2, and 3 per cent. In 1914 the milling tests were continued with samples of wheat with admixtures, viz, 1, 2, and 3 per cent each of corn cockle and kinghead, and 1, 2, 3, and 5 per cent of rye. No milling tests were made with admixtures of hairy vetch, as the experiments of 1912 and 1913 showed very conclusively the detrimental effects which this impurity has on the milling and baking qualities of wheat and flour.

Samples of wheat which contained large amounts of wild-vetch seed were secured by the writer from the 1914 crop as marketed by farmers at country points, and the results of the milling and baking tests of these samples are given in Table IX (p. 20). The results show that the detrimental effects of hairy vetch and of wild vetch in wheat as milled are very similar in character.

DESCRIPTIONS OF THE DIFFERENT IMPURITIES.

RYE.

Rye (*Secale cereale*) is the impurity most common and abundant in hard winter wheat. Millers object to its presence, claiming that it injures the color of the flour, but the opinions of millers differ greatly as to the amount of rye that may be present in wheat before the color of the flour will be affected. Some millers contend that 2 per cent of rye in wheat will injure the color of the flour, while others hold that amounts up to 5 per cent will not noticeably affect the quality of the flour or bread.

Rye was also found in 39.2 per cent of the spring-wheat samples secured, as indicated in Table I, and in one case the farmer's wheat crop contained 14.3 per cent. On account of the excessive amount of rye in this wheat the farmer received 8 cents less per bushel than he would have received had the grain been free from rye. The presence of rye in a considerable percentage of the samples examined was probably due to the fact that wheat containing rye was used for seeding purposes. Frequently wheat is sown on land which was planted in rye the previous season, and the rye shattered during harvest produces a volunteer crop which matures and is harvested with the wheat. Where the wheat crop partially winterkills, the percentage of rye is considerably increased, as rye is not so subject to

winterkilling as wheat. Baking tests with flour milled from wheat samples containing different percentages of rye showed detrimental effects on both the color and the texture of the crumb when above 3 per cent of this impurity was added to the wheat.

Examinations of samples of flour milled from wheat which contained various percentages of rye showed the presence of a considerable number of grayish and greenish yellow specks, especially in the samples containing more than 3 per cent of this ingredient.

Wheat containing a 3 per cent admixture of rye will yield a darker colored flour, showing quite distinctly toward the tail of the mill. When rye is milled alone about 48 per cent of flour is obtained, as shown in Table III (p. 10). Rye flour does not bolt freely, but when blended with wheat in small amounts it seems to cause very little trouble in bolting, since the wheat flour aids the rye flour in passing through the bolting cloth. The fact that the flour yield was but slightly reduced even in samples of wheat with 5 per cent



FIG. 2.—Wheat containing 6 per cent of corn-cockle seed and 8.7 per cent of other foreign matter, as delivered at a country elevator. (Natural size.)

or more of rye would indicate that a large proportion of the rye flour bolted through with the wheat flour. When wheat containing 10 per cent of rye was milled into three grades of flour, the injurious effects of rye were most pronounced in the second-clear flour, as evidenced in the baking results given in Table VI (p. 16).

CORN COCKLE.

Corn cockle (*Agrostemma githago*) is an annual prolific weed, the seed of which is rough, black, and of such a shape and size as to make it difficult to separate from wheat. It is very common, being widely distributed over the United States, and is especially abundant in the sections producing soft red winter, spring, and durum wheats. It is not an uncommon occurrence for wheat to contain 1 or 2 per cent of this weed seed, and occasionally 5 or 6 per cent of corn cockle is present in the grain as marketed (fig. 2). The presence of 1 or 2 per cent of corn cockle in wheat is likely to lower the grade or price given the farmer and will lower the baking qualities of the flour. The fact

that a single plant of corn cockle has been known to yield as high as 2,500 seeds shows it to be an exceedingly prolific and obnoxious weed, which every farmer should strive to eradicate or prevent from getting a start if the farm is not infested.

In milling wheat containing but 1 per cent of corn cockle, black specks, which are finely broken pieces of the outer covering of the seed, appear in the flour. When milled alone, corn-cockle seed will yield from 45 to 50 per cent of flour having a bluish white color and a specky appearance. Baking tests of three grades of flour milled from wheat containing 10 per cent of corn cockle indicated that this impurity was well distributed in each grade of flour (Table VI, p. 16).

Figure 2 represents a sample of spring wheat obtained by the writer from a farmer's wagon as the grain was unloaded at a country grain elevator. The mechanical analysis of this sample showed it to contain by weight 6 per cent of corn cockle, 1 per cent of wild buckwheat, and 7.7 per cent of other grains, which consisted of oats, wild oats, and barley.

The presence of such an amount (6 per cent) of corn cockle in this wheat resulted in a loss to the farmer, not only in the lower price per bushel which he received but in addition a dockage was assessed.

This term "dockage" is used with reference to the foreign matter present in wheat when marketed. It is the custom in the States producing spring wheat which contains a considerable quantity of foul weeds and other foreign matter to deduct from the gross weight of the load a certain amount expressed in pounds per bushel. For example, if a load of 50 bushels of wheat is found to contain 2 pounds of foreign matter for each bushel, then 100 pounds is deducted from the gross weight, and the owner of the grain receives pay for 50 bushels less the 100 pounds of dockage, or 48 bushels and 20 pounds of wheat.

KINGHEAD, OR GREAT RAGWEED.

Kinghead (*Ambrosia trifida*) is an annual weed belonging to the ragweed family, which grows very rank, from 3 to 15 feet high, in moist soil. Consequently, it is found more frequently and much more abundantly in river valleys and in sections where the ground lies low and where there is a good supply of moisture than in well-drained areas or sections with a light rainfall. According to Britton and Brown, this weed is widely distributed over the United States. However, it seems to be a greater pest in the Northwest, especially in Minnesota, North Dakota, and South Dakota, than in the other wheat-producing States.

On account of its shape and size (fig. 1) this seed, like corn cockle, is difficult to clean out of the wheat. One means of removing it, in

addition to the regular grain-cleaning machinery commonly found in mills, is that of floating it out with wheat washers, specially devised machines for cleaning smutty wheat. Since installing this equipment is expensive, few mills have such facilities, and they must depend on the ordinary grain cleaners, which remove but a small percentage of the kinghead seed, often present in quantities as high as 3 or 4 per cent. Unless wheat that contains large amounts of kinghead seed is mixed with a sufficient quantity of clean wheat to reduce the percentage of kinghead to a minimum, the flour produced will be of inferior quality. Such flour contains black specks, which injuriously affect the quality of the bread both in color and texture. The writer secured in a country mill samples of flour milled from wheat containing about 2 per cent of kinghead seed. Baking tests of these samples showed that both the color and the texture of the loaf were very seriously affected. When milled alone, kinghead seed



FIG. 3.—Wheat containing 28 per cent of kinghead seed and 3.5 per cent of other foreign matter, as unloaded from a wagon at a country elevator. (Natural size.)

gave a very low yield (less than 16 per cent) of flour, which was dark gray in color. The flour was readily reduced, the bulk of it being made on the break rolls and the first reduction. On account of the dark color of this flour, a mixture of 1 per cent of kinghead seed in wheat when milled is noticeable in the flour. When wheat containing 10 per cent of kinghead was milled into three grades of flour, the injurious effects of this so-called inseparable ingredient were in evidence in all grades, as shown by the results of the baking tests given in Table VI (p. 16).

Figure 3 shows a sample of spring wheat as grown and delivered to an elevator by a farmer. This sample contained 28 per cent of kinghead seed by weight, in addition to 2 per cent of rye and 1.5 per cent of wild oats. On account of the excessive amount of this practically inseparable weed seed in the wheat, the price and grade were greatly reduced, and, as with the sample which contained corn cockle, a heavy dockage was assessed by the grain buyer.

WILD VETCH.

Wild vetch (*Vicia angustifolia*) is a narrow-leaved species, closely related to common vetch, and is an annual weed growing about 1 to 2 feet high in fields and waste places. The seed is nearly round, black or dark brown in color, and, as a rule, fully as large as corn-cockle seed. For this reason it is difficult to separate it from wheat, and when present in appreciable quantities it lowers the grade and reduces the price given for the wheat. Although this weed is neither so prevalent nor so abundant as corn cockle, yet in some localities, especially in sections producing spring wheat, it is found in such amounts as to be a pest. The species of wild-vetch seed found in the wheat samples secured at country points consisted largely of the narrow-leaved vetch and to a lesser extent the hairy-pod vetch (*Vicia hirsuta*). The latter species has short pods covered with fine, short hairs (hence the



FIG. 4.—Wheat containing 3.8 per cent of wild-vetch seed and 1.5 per cent of other foreign matter, as unloaded from a farmer's wagon at a country elevator. (Natural size.)

name *hirsuta*), while the narrow-leaved vetch has black pods an inch or more in length.

Because it was not feasible to secure a sufficient amount of wild-vetch seed for use in the milling and baking tests which were made to study the effects of such an impurity in wheat, hairy-vetch seed (*Vicia villosa*), which is very similar in size and shape, was substituted for wild vetch. Hairy-vetch seed is less highly colored than seed of the wild vetch, which has a reddish orange-colored meat, and possibly the effect on the color of the crumb of the loaf was less pronounced than would have been the case if wild-vetch seed had been used. Where 1 per cent of hairy-vetch seed is present in wheat as ground, the flour will have a yellowish appearance and a noticeable odor of vetch. When milled alone, hairy-vetch seed gave a flour yield of about 58 per cent. It was hard to bolt, having a somewhat gummy consistency. The color of the flour was similar to that of powdered sulphur and consequently when blended with wheat flour it imparted a yellowish tint to the bread.

Figure 4 shows a sample of spring wheat containing 3.8 per cent of wild-vetch seed by weight, in addition to the other impurities, con-

sisting of 0.5 per cent of wild oats and 1 per cent of pigeon grass and other weed seed. This wheat was obtained from a farmer's wagon as the grain was unloaded at a country elevator. Because the grain buyer considered wild vetch an inseparable impurity which would injure the milling qualities of the wheat, the farmer was given a lower price for his grain than he would have received had the wheat been free from vetch seed.

COMPARATIVE MILLING YIELDS OF WHEAT AND OF ITS IMPURITIES.

Table III shows the yields of bran, shorts, and straight flour obtained in milling wheat in comparison with the yields of these products obtained in milling rye, corn cockle, kinghead, and hairy vetch as used in the milling and baking tests. Averages are given of three tests with wheat and corn cockle and of two tests with rye, kinghead, and hairy vetch.

TABLE III.—*Milling tests of wheat, rye, corn cockle, kinghead, and hairy vetch, showing comparative yields of straight flour, bran, and shorts.*

Ingredient.	Bran.	Shorts.	Straight flour.	Quantity milled.	Machine used in milling.	color of flour.
	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Pounds.</i>		
Wheat.....	12.5	14.7	71.4	120	50-barrel mill.....	White.
Rye.....	13.6	31.3	47.8	113	do.....	Gray.
Corn cockle..	22.9	28.0	47.6	20	Small experimental mill.....	Bluish white.
Kinghead....	52.3	31.9	15.8	5	do.....	Dark gray.
Hairy vetch..	12.9	25.3	57.8	5	do.....	Yellow.

A relatively low yield of flour was secured when each impurity was milled by itself, especially in the test with kinghead seed, from which less than 16 per cent of flour was obtained. The presence of more than 1 per cent of this impurity in wheat as milled resulted in a noticeably decreased flour yield, as shown in Table IV.

Although the flour from each impurity was difficult to bolt when milled alone, when the mixtures of rye, corn cockle, and hairy vetch with wheat were milled the yield of flour was not greatly reduced. In all probability the wheat flour aided in bolting through a greater proportion of the flour from each of the impurities. On account of the decidedly different color of the flour of each impurity from that of wheat flour, the detrimental effects on the color of the bread made from such flour mixtures are very noticeable. (See Table IV.)

MILLING AND BAKING TESTS OF WHEAT CONTAINING IMPURITIES.

TESTS WITH ADMIXTURES OF VARIOUS PERCENTAGES OF EACH IMPURITY.

Table IV gives the results of milling and baking tests with samples of wheat containing certain percentages of the so-called inseparable impurities—rye, corn cockle, kinghead, and hairy-vetch seed. These data are the averages of tests covering three years with rye, kinghead, and corn cockle, with the exception of the tests with 5 per cent and 10

per cent of corn cockle, in which instances tests were made for one year only, and the results obtained in the experiments with hairy vetch are the averages of tests covering two years.

TABLE IV.—*Milling and baking tests of clean wheat and of wheat containing different percentages of rye, corn cockle, kinghead, and hairy vetch.*

Sample description.	Milling yield.			Water absorption.	Volume of loaf.	Score.		Quantity of wheat required per barrel of flour.		Remarks concerning—	
	Bran.	Shorts.	Flour.			Texture of loaf.	Color of crumb.	Bushels.	Pounds.	Crumb.	Dough.
Clean wheat (check)...	P.ct	P.ct	P.ct	P.ct	C.c.						
Wheat with rye:	12.5	14.7	71.4	58.0	2,510	94	96				
1 per cent.....	11.9	16.5	70.0	57.3	2,410	94	95	4	40	do.....	Elastic.
2 per cent.....	11.9	15.9	71.2	57.4	2,430	93	94	4	35	Creamy gray..	
3 per cent.....	12.3	16.1	70.7	57.3	2,440	91	93	4	37	Slightly gray..	Fairly elastic.
5 per cent.....	12.7	16.3	70.0	57.3	2,440	90	92	4	40	Gray.....	
10 per cent.....	12.9	16.5	70.0	57.9	2,370	90	92	4	40	do.....	
Clean wheat (check)...	11.7	15.4	71.8	58.2	2,565	94	97	4	33	Creamy.....	Elastic.
Wheat with corn cockle:											
1 per cent.....	14.8	13.6	70.0	58.1	2,500	93	95	4	40	Creamy gray..	Fairly elastic.
2 per cent.....	16.0	12.9	69.7	57.4	2,470	90	90	4	41	Gray.....	
3 per cent.....	15.7	12.9	70.4	57.7	2,220	86	87	4	38	Very gray.....	(1).
Clean wheat (check)...	12.8	14.1	70.3	62.3	2,765	95	96	4	39	Creamy.....	Elastic.
Wheat with corn cockle:											
5 per cent.....	14.1	15.5	70.1	60.9	1,750	80	82	4	40	Very gray.....	(2).
10 per cent.....	16.5	13.1	69.3	59.4	910	50	70	4	43	do.....	(2).
Clean wheat (check)...	12.5	14.7	71.4	58.0	2,510	94	96	4	34	Creamy.....	
Wheat with kinghead:											
1 per cent.....	13.0	15.3	70.2	57.8	2,445	93	88	4	39	Very gray.....	Elastic.
2 per cent.....	13.9	15.7	69.4	57.8	2,450	92	83	4	42	do.....	
3 per cent.....	14.3	16.8	67.6	57.9	2,400	89	79	4	50	do.....	Fairly elastic.
5 per cent.....	14.6	20.2	63.3	57.9	2,350	86	70	5	11	Dirty gray....	
10 per cent.....	16.2	20.5	61.5	57.8	2,240	80	50	5	19	do.....	
Clean wheat (check)...	11.4	15.5	71.3	58.0	2,450	95	96	4	35	Creamy.....	Elastic.
Wheat with hairy vetch:											
1 per cent.....	14.1	14.4	69.7	57.9	2,115	88	92	4	41	do.....	(3).
2 per cent.....	13.2	12.9	71.2	57.8	2,015	83	90	4	35	Yellow.....	(3).
3 per cent.....	12.8	14.6	71.2	58.2	1,940	78	85	4	35	do.....	(4).
5 per cent.....	12.7	14.3	70.7	58.8	1,835	69	79	4	37	Very yellow....	(5).
10 per cent.....	13.4	15.0	70.2	56.3	1,605	63	68	4	39	do.....	(6).

¹ Fairly elastic, irritating to hands.

² Sticky and "runny;" very irritating to hands.

³ Fairly elastic; odor and flavor of vetch.

⁴ Slightly sticky and "runny;" odor and flavor of vetch.

⁵ Sticky and "runny;" odor and flavor of vetch.

⁶ Short and "runny;" strong odor and flavor of vetch.

A study of Table IV brings out the detrimental effects which the added impurities had on the milling and baking qualities of the wheat. For convenience of discussion the factors of importance from the commercial standpoint may be grouped under two headings, viz, milling quality and baking quality.

MILLING QUALITY.

The amount of flour which can be obtained from a bushel of wheat is of prime importance to the miller, since it is the most valuable mill product. Therefore, any impurity that reduces the yield of flour obtained in milling wheat, or that lowers the quality of the flour, has a direct bearing on the milling value and should receive careful consideration in grading wheat.

The admixture of kinghead seed in wheat greatly reduced the yield of flour, the reduction being especially evident with an increased amount of this impurity, while the addition of different percentages of rye, corn cockle, and hairy-vetch seed did not so materially reduce the amount of flour obtained.

BAKING QUALITY.

One of the prime requisites of flour is that it have good baking qualities, that is, produce a large loaf having good texture and color of crumb, and in addition have the power of absorbing and retaining a large amount of water. Housewives demand a flour having a white or creamy color. Any factor, therefore, which in any way injures the baking qualities of flour, such as reducing the size of the loaf or lowering the color or texture of the bread, should necessarily be considered in placing a valuation on flour and consequently on the grade of wheat from which the flour was milled.

EFFECTS OF IMPURITIES IN WHEAT ON QUALITIES OF FLOUR AND BREAD.

The presence of rye in wheat has a detrimental effect on the loaf volume, and when more than 3 per cent of this ingredient is added the color and texture of the bread will be noticeably injured. The effects of the addition of such impurities as corn cockle, kinghead, or vetch to wheat are much more detrimental in character than where rye is added, as shown in the greater reduction in the size of loaf and the decidedly lower scores given the color and texture of the bread.

With an increased percentage of corn cockle there was a very decided reduction in the loaf volume, with a consequent injurious effect on the texture. In mixing the dough an irritation of the skin of the hands was noticed with the flour milled from wheat containing 3 per cent of corn cockle, with a decided increase in the amount of the irritation when a larger amount of corn cockle was added.

The amount of water absorbed was also considerably less in the tests with flour from wheat containing more than 3 per cent of corn cockle than in the check test with pure wheat flour. When more than 3 per cent of either corn cockle or vetch seed was added to the wheat and made into flour, the dough was "runny" and sticky. In the tests with 3 per cent and 5 per cent admixtures of hairy vetch, there was an apparent increase in the percentage of water absorption as compared with the check sample. However, the remarks concerning the effect on the dough in this connection indicate that an excessive amount of water had been added to the flour, resulting in a "runny" and sticky dough. A smaller amount of water was added to the flour from the 10 per cent mixture of vetch in an attempt to improve the consistency of the dough, but even then it was short and somewhat "runny." A strong and disagreeable odor and flavor of vetch was very noticeable in the bread made from flour of hairy-vetch mixtures.

In these tests with the different impurities described there seemed to be a very close relation between the effects produced on the loaf volume and on the texture of the crumb. Where the volume was greatly decreased, as shown in the results of the tests with corn cockle, a compact loaf of bread with very small pores was obtained, while in the tests with kinghead and rye the pores were much larger and very irregular in shape. Evidently the strength of the gluten was greatly injured by the presence of flour from these various impurities, especially when added in considerable quantities, and corn cockle in large amounts seemed to destroy practically all fermentation.

Figures 5 and 6 graphically illustrate the injurious effects of rye, hairy vetch, kinghead, and corn cockle, on the milling and baking qualities of straight flour made from wheat containing these impurities. The results of the milling and baking tests in this connection are given in Table IV, and the discussion of these results is given on page 11.

Plate I is a reproduction of photographs of bread baked from flour obtained in milling samples of wheat which contained different percentages of rye, corn cockle, kinghead, and hairy vetch showing the detrimental effects of these impurities upon the baking qualities of flour.

TESTS WITH A 10 PER CENT ADMIXTURE OF EACH IMPURITY.

MILLING TESTS.

Table V gives the results of milling tests with samples of wheat containing 10 per cent admixtures of rye, corn cockle, kinghead, and hairy-vetch seed. These samples were milled into three grades of flour—patent, first clear, and second clear. The addition of 10 per cent of kinghead resulted in a great reduction in the yield of total flour, while there was scarcely any difference in the flour yields obtained from the admixtures of rye and corn cockle compared with the check sample of clean wheat. In this experiment but one milling test was made with each admixture and with the clean wheat. In the test with the 10 per cent admixture of hairy vetch, where three grades of flour were made, there was an apparent increase of 1 per cent of total flour over that of the check sample. Previous tests with hairy vetch indicated that this impurity had little, if any, effect on the flour yield, and the result of this one test with a 10 per cent admixture of hairy vetch would be within the limits of variation, especially since in several tests with check samples of this lot of wheat, milled as straight flour in connection with other tests made in 1913, there was a range of 1.5 per cent in the flour yields obtained, the maximum yield being 71 per cent.

With the exception of the test with rye, the amount of patent flour obtained from the samples containing impurities was noticeably less

than in the check test with clean wheat, and the percentage of the lower grades of flours was correspondingly increased. This fact is of great importance in placing a valuation on wheat which contains any considerable amount of these objectionable impurities, for a reduction in the yield of high-grade flour that can be obtained is a financial loss to the miller, and the grade of such wheat should be lowered according to the percentage of admixture of the impurity.

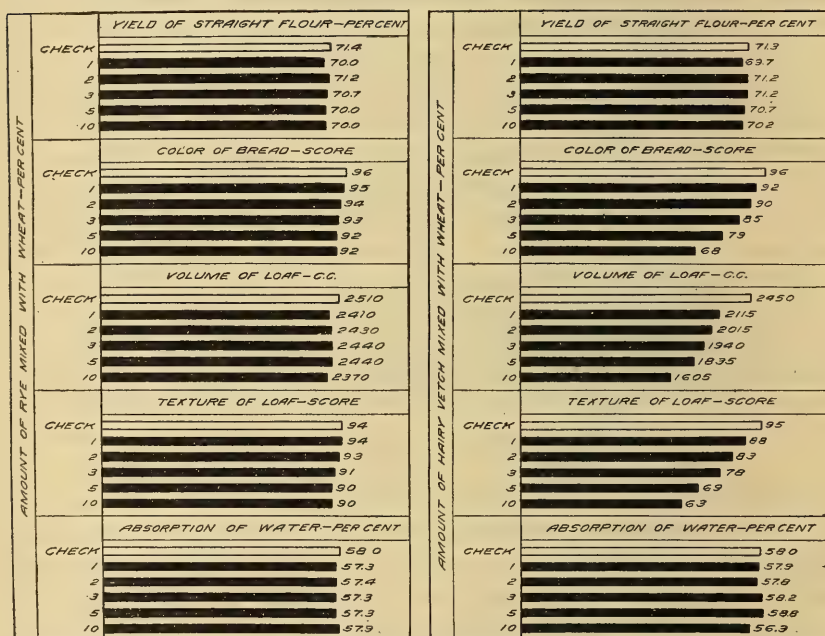


FIG. 5.—Diagram showing the results of the milling and baking tests of straight flour milled from wheat containing various percentages of rye and hairy vetch.

TABLE V.—Milling tests of clean wheat and of wheat containing 10 per cent admixtures of rye, corn cockle, kinghead, and hairy vetch, milled into three grades of flour.

Description of sample.	Moisture after tempering.	Bran.	Shorts.	Total flour.	Total flour made.			Quantity of wheat used per barrel of flour.		Color effects on flour.
					Pat-ent.	First clear.	Second clear.	Bush-els.	Pounds.	
Clean wheat (check)	P. ct. 14.9	P. ct. 14.7	P. ct. 13.5	P. ct. 69.5	P. ct. 76.5	P. ct. 19.5	P. ct. 4.0	4	42	White.
With 10 per cent—										
Rye.....	14.6	14.6	13.8	69.3	77.2	18.2	4.6	4	43	Slightly gray. ¹
Corn cockle....	14.5	14.3	15.2	69.2	74.1	21.8	4.1	4	43	Bluish tint and black specks. ²
Kinghead.....	14.9	18.9	20.3	60.4	71.2	24.3	4.5	5	24	Gray. ³
Hairy vetch....	15.0	13.7	13.3	70.5	74.8	22.4	2.8	4	38	Yellow. ³

¹ Most evident in second clear.

² Very injurious to all grades.

³ Injury evident in all grades.

BAKING TESTS.

Table VI gives the results of baking tests with flour milled from samples of wheat containing 10 per cent admixtures of rye, corn cockle, kinghead, and hairy vetch. These results are interesting, especially when correlated with the milling results given in Table V. The greatest injury of rye is seen in its effects in the second-clear flour, where the scores for the color and texture of the crumb were materially lowered. More second-clear flour was obtained from the test with rye than from the tests with any of the other impurities.

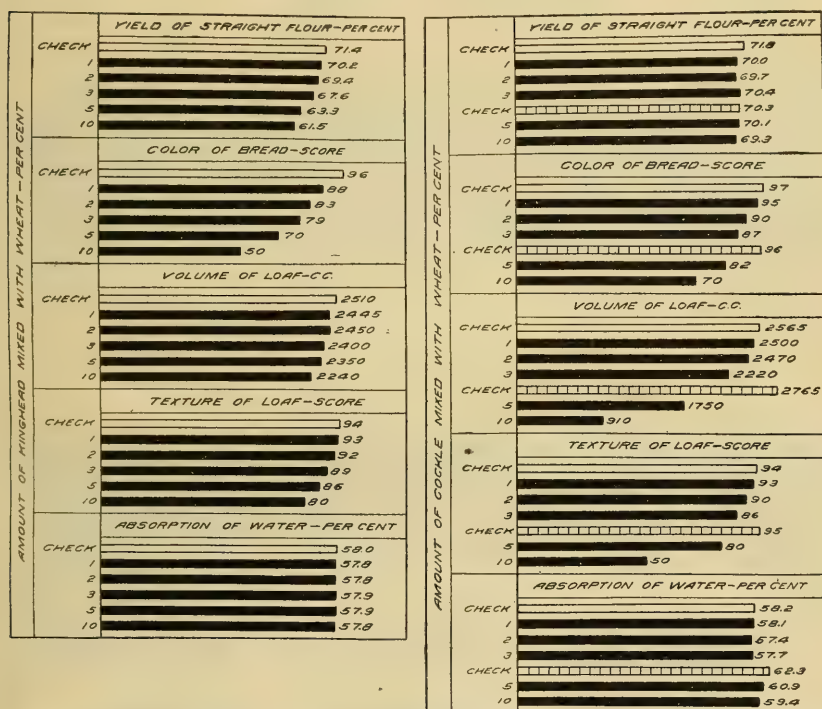


FIG. 6.—Diagram showing the results of the milling and baking tests of straight flour milled from wheat containing various percentages of kinghead and corn cockle.

Corn cockle was well distributed in all three grades of flour, as shown by the exceedingly detrimental effects for all factors given.

Even though the amount of kinghead in each grade of flour was small, the injurious character of this impurity was especially noticeable in the color of the crumb and the texture of the loaf.

That the flour from hairy-vetch seed was well distributed in all three grades of flour is evidenced by the deleterious effects on volume, color, and texture of the loaf. As in the tests where the one grade, straight flour, was made, rye seemed to have a less injurious effect on the baking qualities in these tests with three grades of flour than did corn cockle, kinghead, and vetch.

TABLE VI.—*Baking tests with patent, first-clear, and second-clear flour, milled from clean wheat and from wheat containing 10 per cent admixtures of rye, corn cockle, kinghead, and hairy vetch.*

Description of sample.	Water absorption.	Volume of loaf.	Score.		Remarks.	
			Color of crumb.	Texture of loaf.	Crumb.	Dough.
PATENT FLOUR.						
Clean wheat (check).....	P. ct. 62.4	C. c. 2,670	95	94	Creamy gray....	
With 10 per cent—						
Rye.....	59.7	2,485	95	95	Creamy.....	
Corn cockle.....	58.5	1,200	86	55	Gray.....	(1).
Kinghead.....	62.4	2,705	53	84	Dirty gray.....	Slightly "runny."
Hairy vetch.....	60.9	1,720	72	74	Very yellow.....	(2).
FIRST-CLEAR FLOUR.						
Clean wheat (check).....	61.5	2,180	86	85	Gray.....	
With 10 per cent—						
Rye.....	59.4	2,177	78	85	Dirty gray.....	
Corn cockle.....	55.6	900	66	50	do.....	(1).
Kinghead.....	62.1	2,250	50	85	do.....	"Runny."
Hairy vetch.....	62.1	1,590	55	70	Dark yellow.....	(3).
SECOND-CLEAR FLOUR.						
Clean wheat (check).....	62.4	1,882	83	88	Gray.....	
With 10 per cent—						
Rye.....	61.2	1,735	58	70	Dirty gray.....	
Corn cockle.....	55.3	810	45	50	Black.....	(1).
Kinghead.....	62.6	2,020	50	80	Dirty gray.....	"Runny."
Hairy vetch.....	61.8	1,420	50	60	Dirty yellow.....	(4).

¹ Sticky and "runny"; irritating to hands.

² Short and slightly "runny"; strong odor of vetch.

³ Short and slightly "runny"; very strong vetch odor.

⁴ Short and "runny"; very strong vetch odor.

The comparative results of the baking tests of patent, first-clear, and second-clear flour milled from wheat samples containing 10 per cent admixtures of rye, corn cockle, kinghead, and hairy vetch, as

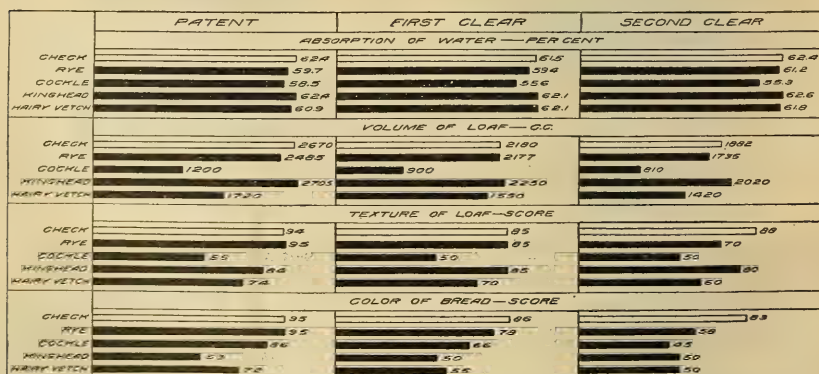


FIG. 7.—Diagram showing the results of baking tests with patent, first-clear, and second-clear flour milled from wheat containing 10 per cent admixtures of rye, corn cockle, kinghead, and hairy vetch.

given in Table VI, are shown diagrammatically in figure 7. The presence of corn cockle in flour very perceptibly lessens the percentage of water that will be absorbed, and both corn cockle and hairy vetch

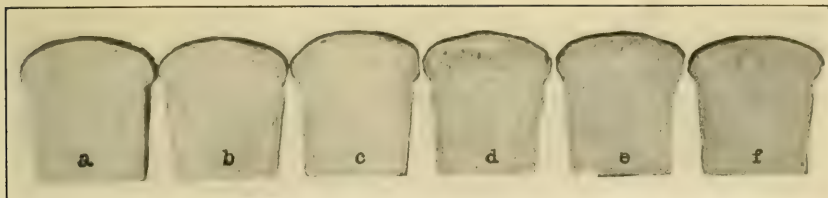


FIG. 1.—Loaves from clean wheat (*a*) and from wheat containing admixtures of rye: *b*, 1 per cent; *c*, 2 per cent; *d*, 3 per cent; *e*, 5 per cent; *f*, 10 per cent.

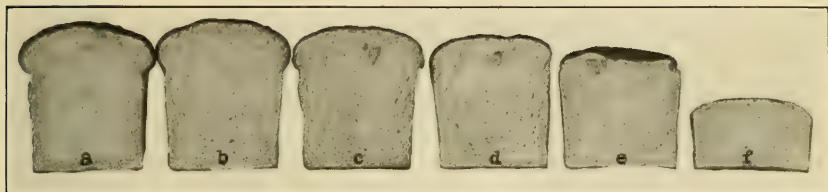


FIG. 2.—Loaves from clean wheat (*a*) and from wheat containing admixtures of corn cockle: *b*, 1 per cent; *c*, 2 per cent; *d*, 3 per cent; *e*, 5 per cent; *f*, 10 per cent.

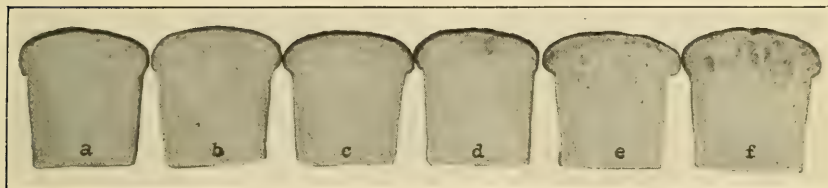


FIG. 3.—Loaves from clean wheat (*a*) and from wheat containing admixtures of kinghead seed: *b*, 1 per cent; *c*, 2 per cent; *d*, 3 per cent; *e*, 5 per cent; *f*, 10 per cent.



FIG. 4.—Loaves from clean wheat (*a*) and from wheat containing admixtures of hairy-vetch seed: *b*, 1 per cent; *c*, 2 per cent; *d*, 3 per cent; *e*, 5 per cent; *f*, 10 per cent.

CROSS SECTIONS OF LOAVES OF BREAD OBTAINED IN CONNECTION WITH THE MILLING AND BAKING TESTS WITH SAMPLES OF WHEAT CONTAINING VARIOUS PERCENTAGES OF RYE, CORN COCKLE, KINGHEAD, AND HAIRY VETCH. THE RESULTS OF THESE TESTS ARE GIVEN IN TABLE IV.

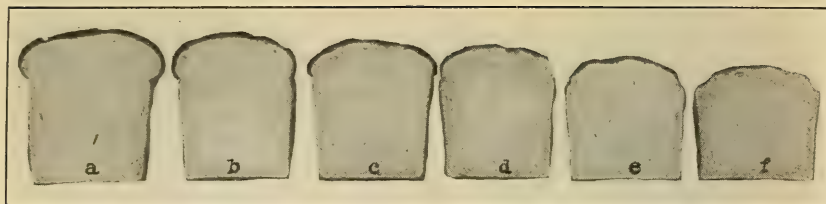


FIG. 1.—Effects of 10 per cent admixture of rye in wheat: *a*, Patent flour (check); *b*, patent flour (10 per cent rye); *c*, first-clear flour (check); *d*, first-clear flour (10 per cent rye); *e*, second-clear flour (check); *f*, second-clear flour (10 per cent rye).

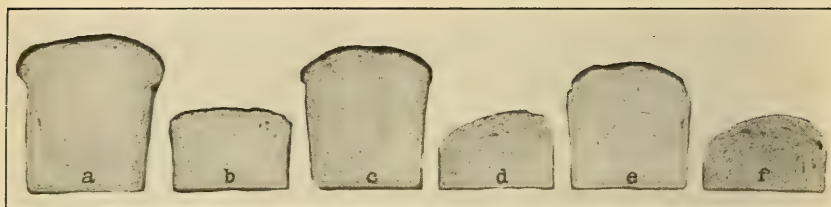


FIG. 2.—Effects of 10 per cent admixture of corn cockle in wheat: *a*, Patent flour (check); *b*, patent flour (10 per cent corn cockle); *c*, first-clear flour (check); *d*, first-clear flour (10 per cent corn cockle); *e*, second-clear flour (check); *f*, second-clear flour (10 per cent corn cockle).



FIG. 3.—Effects of 10 per cent admixture of kinghead seed in wheat: *a*, Patent flour (check); *b*, patent flour (10 per cent kinghead seed); *c*, first-clear flour (check); *d*, first-clear flour (10 per cent kinghead seed); *e*, second-clear flour (check); *f*, second-clear flour (10 per cent kinghead seed).



FIG. 4.—Effects of 10 per cent admixture of hairy-vetch seed in wheat: *a*, Patent flour (check); *b*, patent flour (10 per cent hairy-vetch seed); *c*, first-clear flour (check); *d*, first-clear flour (10 per cent hairy-vetch seed); *e*, second-clear flour (check); *f*, second-clear flour (10 per cent hairy-vetch seed).

CROSS SECTIONS OF LOAVES OF BREAD OBTAINED IN CONNECTION WITH THE BAKING TESTS WITH PATENT, FIRST-CLEAR, AND SECOND-CLEAR FLOUR, MILLED FROM WHEAT CONTAINING 10 PER CENT ADMIXTURES OF RYE, CORN COCKLE, KINGHEAD, AND HAIRY VETCH. THE RESULTS OF THESE TESTS ARE GIVEN IN TABLE VI.

have an especially injurious effect on the loaf volume and texture. The color of the crumb of bread from flour that is milled from wheat containing large amounts of corn cockle, kinghead, and vetch is practically destroyed.

The information given in Table VI and graphically shown in detail in figure 7 is summarized in figure 8. The factors taken into consideration in making up this illustration are the percentage of absorption of water, volume of loaf, and texture and color of loaf for patent, first-clear, and second-clear flour milled from samples of wheat containing 10 per cent admixtures of rye, kinghead, hairy vetch, and corn cockle.

The total scores given the loaves of bread from the samples containing admixtures of impurities are graphically compared with the scores given the check sample of clean wheat, which is used as the standard for comparison, with a rating or score of 100.

In this figure the impurities are arranged in the order of their detrimental influence on the baking qualities, beginning with rye, which, as a whole, had the least injurious effects. Corn cockle is thus shown to be a much more objectionable impurity than any of the others used in the tests, the score in every instance falling far below that of any of the other impurities.

Plate II is a reproduction of photographs of bread baked from patent, first-clear, and second-clear flour obtained in milling wheat samples containing 10 per cent admixtures of rye, corn cockle, kinghead, and hairy vetch, and it illustrates the deleterious effects which these impurities have on the baking quality of flour.

TESTS WITH FLOUR BLENDS.

Tests were made with blends of wheat flour and definitely known percentages of flour from rye, corn cockle, kinghead, and hairy-vetch seed, for additional study of the effects of these impurities on the baking qualities. The flour used in these tests was obtained in milling each of the ingredients represented in Table III. The results of the baking tests with blends of wheat flour with each of these impurities are given in Table VII. A blend of 0.5 per cent was in every instance injurious, the detrimental effects being most apparent in the color of

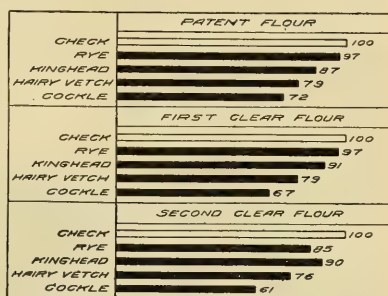


FIG. 8.—Diagram comparing the summarized loaf scores, showing the detrimental effects of 10 per cent admixtures of rye, kinghead, hairy vetch, and corn cockle in wheat on the baking qualities of patent, first-clear, and second-clear flour. Comparison is made with the check test with clean wheat.

the bread, and with but 1.5 per cent blends the deleterious effects on the color and texture of the bread are especially noticeable.

Blends of rye and corn-cockle flour give a grayish tinge to the crumb, while the addition of kinghead flour results in a loaf with a dirty looking crumb. Hairy-vetch blends give to the bread a yellowish color and a strong and disagreeable flavor and odor characteristic of vetch.

TABLE VII.—*Baking tests with wheat flour blended with different percentages of flour made from rye, corn cockle, kinghead, and hairy vetch.*

Sample description (flour blends).	Water absorption.	Score.		Remarks concerning crumb.
		Texture of loaf.	Color of crumb.	
Wheat flour (check).....	<i>Per cent.</i> 58.2	93	95	Creamy.
Wheat flour with rye flour:				
0.5 per cent.....	58.2	90	92	Creamy gray.
0.75 per cent.....	58.2	89	91	Do.
1.0 per cent.....	58.2	88	89	Do.
1.5 per cent.....	57.1	86	85	Do.
Wheat flour (check).....	57.9	94	95	Creamy.
Wheat flour with corn-cockle flour:				
0.5 per cent.....	57.6	93	89	Creamy gray.
0.75 per cent.....	57.9	91	88	Do.
1.0 per cent.....	57.9	91	87	Do.
1.5 per cent.....	57.9	89	85	Do.
Wheat flour (check).....	57.9	95	95	Creamy.
Wheat flour with kinghead flour:				
0.5 per cent.....	57.6	91	86	Dirty gray.
0.75 per cent.....	57.6	90	80	Do.
1.0 per cent.....	57.9	89	75	Very dirty gray.
1.5 per cent.....	57.4	84	60	Do.
Wheat flour (check).....	57.9	92	95	Creamy.
Wheat flour with hairy-vetch flour:				
0.5 per cent.....	57.4	91	92	Creamy yellow.
0.75 per cent.....	57.9	90	91	Yellow.
1.0 per cent.....	57.6	89	90	Do.
1.5 per cent.....	57.6	86	87	Do.

TESTS WITH WHEAT CONTAINING KINGHEAD SEED.

Table VIII gives a comparison of the results of milling and baking tests of samples of wheat containing kinghead seed, as delivered at a country elevator, with the results of tests of samples of the same wheat from which the kinghead was removed by hand picking. In these tests two samples of spring wheat, one a variety known as Blue-stem, with 3.6 per cent of kinghead, and the other a bearded spring wheat known as Velvet Chaff, containing 4.5 per cent of kinghead seed, were each divided into two portions. One part was then milled with the kinghead, while from the other part the kinghead seed was removed by hand picking and the clean wheat milled. The detrimental effects of the presence of this impurity in wheat are seen in the reduced flour yield, a smaller loaf volume, and a considerably poorer crumb texture, while the color score of the loaf is as low as that given bread made from low-grade flour, since the crumb was

dark gray in color. As shown in figure 9, *b*, the pores of the loaf are large and very irregular in shape in the bread made from wheat containing 4.5 per cent of kinghead seed when milled.

TABLE VIII.—*Milling and baking tests with samples of wheat before and after the kinghead seed was removed.*

Description of sample.	Flour yield.	Water absorption.	Volume of loaf.	Score.		Remarks concerning crumb.
				Texture of loaf.	Color of crumb.	
Bluestem wheat:	<i>Per cent.</i>	<i>Per cent.</i>	<i>C. c.</i>			
With 3.6 per cent of kinghead.	70.8	62.4	2,365	80	60	Dirty gray.
Free from kinghead.....	72.6	62.6	2,395	84	86	Gray.
Velvet Chaff wheat:						
With 4.5 per cent of kinghead.	70.7	61.2	2,215	75	50	Dirty gray.
Free from kinghead.....	71.0	61.2	2,325	90	93	Creamy gray.

TESTS WITH WHEAT CONTAINING WILD-VETCH SEED, AS GROWN.

Table IX gives the results of milling and baking tests of two samples of spring wheat obtained by the writer from farmers' granaries. Each sample contained a large amount of wild-vetch seed and represented the crops as grown. Two kinds, or species, of wild-vetch seed were found in these samples. The bulk of the seed was narrow-leaved vetch (*Vicia angustifolia*), and the remainder was the hairy-pod vetch (*Vicia hirsuta*).



FIG. 9.—Loaves of bread made from wheat free from kinghead seed (*a*) and from wheat containing 4.5 per cent of kinghead seed (*b*).

A comparison is given of the results of tests of wheat containing wild-vetch seed, with the results of tests of the same lot of wheat from which the vetch seed was removed by hand picking. One of the samples contained 17.7 per cent and the other 10.3 per cent of wild-vetch seed after being cleaned and scoured with the mill machinery. The fact that the mill cleaners failed to remove the vetch seed shows that this is practically an inseparable impurity. In fact, the grain buyer for the mill in the locality where this wheat was grown refused to purchase this wheat, which contained such a large amount of wild-vetch seed, claiming that it could not be removed from the grain and that it would be a risky undertaking to make flour from such wheat.

After these samples were cleaned as well as was possible with the small milling separator and scoured twice with the scourer of the

North Dakota Agricultural College mill, they were thoroughly mixed and divided into two portions. One part containing the wild-vetch seed was then milled, while from the other part the wild-vetch seed was removed by hand picking and the clean wheat thus obtained was milled.

The detrimental effects of the presence of wild-vetch seed in wheat as milled are very apparent for all factors given in the tabulation. The injurious effects are noticeably greater in the test with the sample of wheat containing 17.7 per cent of this impurity than in the test with wheat in which there was 10.3 per cent of wild-vetch seed.



FIG. 10.—Loaves of bread from wheat before and after wild-vetch seed was removed: *a*, With 17.7 per cent vetch seed; *b*, after vetch seed was removed; *c*, with 10.3 per cent vetch seed; *d*, after vetch seed was removed.

TABLE IX.—*Milling and baking tests with samples of spring wheat before and after the wild-vetch seed was removed.*

Description of sample.	Flour yield.	Water absorption.	Volume of loaf.	Score.		Remarks concerning crumb.
				Texture of loaf.	Color of crumb.	
Spring wheat:	<i>Per cent.</i>	<i>Per cent.</i>	<i>C. c.</i>			
With 17.7 per cent of wild vetch.	66.8	53.2	1,765	70	60	Yellowish gray.
Free from wild vetch.....	68.4	58.2	2,500	95	97	Creamy.
With 10.3 per cent of wild vetch.	66.5	54.4	2,050	80	75	Yellowish gray.
Free from wild vetch.....	67.6	58.5	2,475	97	98	Creamy.

Figure 10 is a reproduction of a photograph of the loaves of bread baked from flour milled from samples of wheat containing wild-vetch seed. The results of the tests in this connection are given in Table IX.

ANALYSES OF WHEAT, OF THE IMPURITIES, AND OF FLOUR CONTAINING ADMIXTURES.

Samples of patent, first-clear, and second-clear flour obtained in milling samples of wheat containing 10 per cent admixtures of rye, corn cockle, kinghead, and hairy vetch were submitted to the Bureau of Chemistry of the United States Department of Agriculture for chemical analyses, and the results obtained are given in Table X. A study

of this table brings out the following points: (1) The percentage of ash is greater in every instance in the flour containing the impurities than in the pure wheat flour. (2) The percentage of ether extract (fat) of corn cockle and kinghead seed is higher than that of wheat and is likewise greater in all three grades of flour containing these impurities than in the flour from clean wheat. (3) The percentage of protein in the poorer grades of flour (first and second clear) is relatively higher in the flour containing impurities than in the flour from clean wheat, with the exception of the first-clear flour from the 10 per cent rye mixture. (4) The percentage of crude fiber is considerably greater in the first-clear and second-clear flours from the admixture of corn cockle, kinghead, and hairy vetch than in the same grade of flour from pure wheat. (5) The acidity of the first-clear and second-clear flour from corn-cockle seed and vetch-seed mixtures is noticeably higher than that of the same grades of flour from the check sample of clean wheat.

The results of the chemical analyses indicate that the flour from the different impurities was distributed to some extent in all three grades of flour, a larger proportion in most instances going into the first-clear and second-clear flours.

TABLE X.—*Chemical analyses of wheat, rye, corn cockle, kinghead, and hairy vetch and of patent, first-clear, and second-clear flour milled from samples of wheat containing 10 per cent admixtures of these four impurities.*

[Moisture and undetermined, including nitrogen-free extract, not given.¹]

Description of sample.	Air-dry samples (per cent).							Acidity as acetic.
	Ash.	Ether extract.	Protein.	Crude fiber.	Pentosans.	Invert sugar.	Sucrose.	
Wheat.....	1.74	1.91	15.44	2.62	7.10	0.14	1.88	0.25
Rye.....	1.97	1.55	12.19	2.38	10.02	.13	2.69	.27
Corn cockle.....	3.40	6.01	15.44	6.49	6.02	.32	1.58	.25
Kinghead.....	2.99	3.33	11.25	44.88	18.97	.14	.60	.73
Hairy vetch.....	2.84	.83	28.56	7.18	6.15	.02	1.55	.87
PATENT WHEAT FLOUR.								
Wheat (check).....	.50	1.16	12.88	.15	2.99	.18	1.12	.12
Wheat with 10 per cent—								
Rye.....	.58	1.19	12.48	.17	3.31	.25	1.21	.12
Corn cockle.....	.55	1.40	12.48	.17	3.67	.22	1.26	.11
Kinghead.....	.60	1.87	13.51	.17	3.35	.30	1.17	.11
Hairy vetch.....	.76	1.25	14.88	.25	3.75	.20	1.37	.27
FIRST-CLEAR WHEAT FLOUR.								
Wheat (check).....	.72	1.60	13.91	.21	3.25	.20	1.45	.16
Wheat with 10 per cent—								
Rye.....	.77	1.54	13.28	.20	3.87	.21	1.57	.17
Corn cockle.....	.92	2.32	14.25	.27	3.12	.36	1.46	.25
Kinghead.....	.79	2.13	14.48	.26	5.82	.30	1.44	.17
Hairy vetch.....	.91	1.62	14.94	.36	4.31	.26	1.65	.33
SECOND-CLEAR WHEAT FLOUR.								
Wheat (check).....	.80	1.86	13.91	.23	3.07	.22	1.65	.18
Wheat with 10 per cent—								
Rye.....	.95	1.98	14.48	.24	3.86	.25	2.55	.22
Corn cockle.....	1.20	3.06	16.02	.41	4.10	.38	1.97	.34
Kinghead.....	.92	2.87	14.88	.43	3.45	.34	1.62	.19
Hairy vetch.....	1.12	2.09	16.65	.53	3.49	.23	2.00	.39

¹ Chemical analyses by Dr. J. A. Le Clerc, Chief of the Plant-Chemistry Laboratory, Bureau of Chemistry.

SPECIAL CLEANING DEVICES.

SPIRAL CLEANER FOR REMOVING ROUND SEEDS FROM GRAIN.

Machines especially devised for removing round seeds from grain and screenings are advertised in various grain papers and catalogues of firms manufacturing grain-cleaning machinery. One machine used to separate vetch from wheat or rye consists of an upright spiral tube divided into several sections. The grain containing vetch is fed into the top and follows its course down the spiral steel tubes. The round seed travels more rapidly and finally gets into the outer tube or section, while irregularly shaped seeds and lighter matter move less rapidly and are discharged from the openings of the tubes nearer the center. Such machines require very little space, no power (being operated by gravity), and scarcely any watching. The capacity of these machines for cleaning grain thoroughly is very small, as only a few bushels per hour can be cleaned. They are very useful in separating vetch from rye or wheat where clean grain is desired for seeding purposes, but they have insufficient capacity for use in grain elevators or flour mills.

THE COCKLE CYLINDER.

In addition to the grain cleaners usually found in mills for preparing wheat for grinding, specially constructed machines known as cockle cylinders are frequently installed for the purpose of removing from the grain corn-cockle seed and other foreign matter and seeds of similar size and shape.

Although these machines are comparatively inexpensive, a considerable quantity of wheat consisting of broken, small, and shriveled kernels is taken out in removing the corn cockle. This increases the mechanical loss that results from cleaning grain, and a portion of the corn-cockle seed is left in wheat after being cleaned with the cockle cylinder.

MECHANICAL ANALYSES OF CORN-COCKLE SCREENINGS.

Table XI gives the mechanical analyses of four samples of corn-cockle screenings secured from country mills. Sample No. 73719 represents screenings removed in cleaning wheat with the cockle cylinder. Half a pound of screenings was obtained from each bushel of wheat cleaned. Analysis of this sample showed that but 1.3 per cent was corn cockle and 93.6 per cent was wheat. In the other three samples a relatively small percentage of the screenings consisted of corn cockle, while a high percentage was wheat. Sample No. 80994 represents corn-cockle screenings removed by the cleaning machinery in general use in country mills, and the other three samples are screenings removed from wheat with cockle cylinders. Such

screenings are not an entire loss to the miller, since he can often sell them at a fair price for chicken or stock feeding. Corn-cockle screenings are sometimes discriminated against, since it is known that corn-cockle seed contains a poisonous substance known as saponin, or sapotoxin, which is said to have caused trouble in instances where screenings containing a considerable quantity of cockle have been fed to chickens and other animals. Feeding tests have been made by different experimenters with varying results. Some found that young animals were more susceptible and more seriously affected than mature ones, while other experimenters fed varying amounts of corn-cockle seed to different kinds of animals with no apparent symptoms of poisoning. Further experimentation along this line is necessary before any definite conclusions can be drawn concerning the amount of corn-cockle seed that may be fed to different classes of animals before ill effects are produced.

TABLE XI.—*Mechanical analyses of samples of corn-cockle screenings.*

Laboratory No.	Constituents (per cent).														
	Foreign matter.														
	Other grains.					Weed seeds, etc.									Wheat (small and broken kernels).
	Barley.	Flax.	Oats.	Rye.	Wild oats.	Wild buckwheat.	Mustard.	Cow cockle.	Pigeon grass.	Wild rose.	Garlic.	Chaff, dirt, etc.	Corn cockle.	Total.	
66634...	.5	.5	¹ T.	¹ T.	.5	2.5	1.0	0	2.0	2.0	0	0	15.0	24.0	76.0
73590...	¹ T.	.4	¹ T.	0	¹ T.	20.0	1.2	2.4	1.6	.8	0	0	20.4	46.8	53.2
73719...	.4	.4	¹ T.	¹ T.	1.0	1.0	.3	.4	1.0	.6	0	0	1.3	6.4	93.6
80994...	0	0	.2	0	0	0	0	0	0	0	1.2	2.6	11.5	15.5	84.5

¹ T.—trace, the amount found being less than 0.1 per cent.

SUMMARY.

Wheat as grown and as marketed frequently contains certain impurities such as rye, kinghead (great ragweed seed), corn-cockle seed, and wild-vetch seed.

Grain men and millers consider these impurities as inseparable, as they are not easily removed from wheat with the cleaning machinery in general use in grain elevators and flour mills. It is claimed that the presence of these so-called inseparable impurities in wheat as milled injuriously affects the baking qualities of the flour. For this reason wheat containing an appreciable amount of any of these impurities is penalized either by lowering the grade or by reducing the price.

Special experiments were made to ascertain what effects the presence of rye, kinghead, corn cockle, or wild-vetch seed in wheat has on milling and baking qualities.

A sufficient amount of wheat of one variety was purchased to make all the milling tests for each year, in order to have a basis for comparison of all tests with the impurities. Different percentages of each impurity were mixed with wheat samples, which were then milled and baking tests made with the flour.

The results of these tests show that the presence of more than 2 per cent of any of these impurities in wheat as milled has detrimental effects on the milling and baking qualities.

The deleterious effects of rye in wheat are less pronounced than those of corn cockle, kinghead, or vetch seed. If present in wheat in amounts as high as 2 per cent or more, rye lowers the quality of the bread.

Corn cockle seems to have exceedingly injurious effects on the volume, color, and texture of the loaf, and when present in amounts of 3 per cent or more reduces the percentage of water absorption of the flour.

Kinghead in wheat in appreciable amounts materially lowers the flour yield, and the detrimental effects of this impurity in the flour are especially noticeable in the dirty color of the crumb and the coarse, uneven texture of the bread baked from such flour.

Vetch seed in wheat will reduce the size of the loaf and give to the bread a yellowish tinge and a disagreeable odor and flavor characteristic of vetch.

Corn-cockle seed is a more objectionable impurity in wheat than rye, kinghead, or wild vetch, since it contains a poisonous element known as saponin, or sapotoxin, the presence of which is very undesirable in flour or bread.

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NOTES ON FIVE NORTH AMERICAN BUFFALO
GNATS OF THE GENUS *SIMULIUM*.By ARTHUR W. JOBBINS-POMEROY,¹ *Entomological Assistant*.

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INTRODUCTION.

Certain species of the insects known as "buffalo gnats" are important enemies of man and domestic animals in the United States as well as in other countries. Although the principal area of abundance in North America is in Canada and the Northern States, outbreaks of pests of this group occur as far south as Louisiana and Florida. While they are dependent upon running water for development, they make use of very small streams and, to some extent, of irrigation ditches, and are consequently found occasionally in considerable numbers in the drier parts of the country.

About 20 years ago buffalo gnats attracted great attention along the lower Mississippi River. They frequently became so abundant that plantation operations were stopped on account of very painful attacks against live stock as well as human beings. These great outbreaks were due to conditions established by the overflow of the Mississippi River. The perfection of the levee system has changed these conditions so that the outbreaks are less frequent and of greatly reduced severity. Nevertheless, these insects are still abundant enough to be considered a pest in the Mississippi Valley as well as in many other portions of the South.

The damage done by buffalo gnats results from their painful bites and the loss of blood which ensues. When they are abundant they

¹ Resigned Nov. 20, 1914.

NOTE.—This paper is of interest to persons living east of the Mississippi River.

sometimes cause the death of live stock. At the present time no cases of disease transmission can be attributed definitely to buffalo gnats, but there is a possibility that future investigations will show some important connection with the transmission of diseases.

All of these considerations make it advisable to place on record a considerable number of observations which will serve as a basis for the control of these insects wherever they occur.

The major part of the biological experiments outlined in this paper were carried on at Spartanburg, S. C. The author wishes to express his thanks to Mr. A. H. Jennings, under whose direction the work was done, to the Thompson-McFadden Pellagra Commission for many courtesies received, and to the directors of the Spartanburg Hospital for the generous way in which they afforded laboratory accommodations and facilities.

THE ADULT STAGE.

DESCRIPTION OF EXTERNAL ANATOMY.

The adults of the genus *Simulium* are usually very small, the largest known North American species (*S. pictipes*) not measuring more than 4 mm. in length. They are compact in shape, the head being decidedly small in proportion to the rest of the body, and the thorax greatly developed and curiously humped. In some species the thorax and abdomen are very pubescent, in others almost naked. In color the different species vary greatly, ranging from brilliant iridescent yellow and various shades of gray to almost black.

The species of *Simulium* are holoptic in the male and dichoptic in the female. In the female the facets of the eyes have an equal gradation in size, diminishing somewhat toward the margin. In the male the facets suddenly decrease in size along a line extending on each side from the antennal socket around to the post-genæ, giving the lower portion of the eye the appearance of being divided off by a suture. In color the eyes are usually iridescent bronze in the female and deep iridescent red in the male. Ocelli are wanting in both sexes.

The antennæ are short, moniliform, and 11-segmented. In the species here dealt with the antennæ of the female have the first segment short and cup-shaped. The second is longer, the apical end bearing a chitinous ring which serves as the point of attachment for the third segment, which is nearly the same in length as the second, but pedicellate. The remaining segments are nonpedicellate, broadly joined. Segments 4, 5, 6, 7, 8, and 9 are subequal. The tenth segment is slightly longer. The eleventh is the longest of the entire antenna, narrows to a point at the apical end, and bears from two to three short, strong bristles. The first two segments are minutely pubescent, with a few strong bristles on the apical portion; the re-

maining segments are densely covered with minute pubescence interspersed thickly with stronger hairs. The antennæ of the male are similar in structure to those of the female, except that they are more slender and have the third segment much longer, twice the length of any of the succeeding segments, and the tenth segment usually the same length as the one immediately preceding it. (Figs. 1 and 2.)

The mouth parts are modified in both sexes into a piercing beak, somewhat similar to that of the Tabanidæ. In the male the organs have become greatly reduced both in strength and armature, so that they are apparently unable to pierce the skin of vertebrates.

DESCRIPTIONS OF INTERNAL ANATOMY.

DIGESTIVE SYSTEM.

Pl. I, fig. 2.

The following is a description of the digestive organs of *Simulium venustum*. The diverticulum of the oesophagus, or sucking stomach (*ve*), which is sometimes described as the midintestine or stomach, and whose function seems to be primarily that of a reservoir for blood, is a large membranous bag capable of great distention. At its caudal end it narrows to the constriction known as the pyloric valve (*jp*). This is the place of attachment of the Malpighian tubes.

The Malpighian tubes (*m, m*), which are greatly developed in this insect, are four in number and are constricted at intervals, with corresponding lobular enlargements. They extend from the base of the diverticulum to its cephalic end, turning again caudad, and ending, as far as can be ascertained, in a small blind nodule. They are opaque white in specimens which have not fed, or specimens dissected on emergence, but show remarkable changes in color at various periods after engorgement. Sometimes they are pink, sometimes rather brownish, and in specimens which have engorged and lived for 40 hours they become checkered brown with transparent intervals.

The ileum (*i*), which is situated immediately below the pyloric valve, is an elongate, rounded intestine, somewhat curved when in its natural position. The substance which it contains is invariably more solid than that found in the diverticulum, large granules being frequently present.



FIG. 1.—*Simulium venustum*. Antenna of adult female. Greatly enlarged. (Original.)



FIG. 2.—*Simulium venustum*. Antenna of adult male. Greatly enlarged. (Original.)

Toward its caudal end the ileum narrows into what is probably the colon (*c*), which leads in turn directly into the sacklike rectum. This is round in shape, transparent, deeply striated, and capable of great contraction and distention. It contains six large oval glands (*rg*), which are somewhat similar to the rectal glands of *Stomoxys calcitrans* L. At its caudal end the rectum contracts into the external orifice, or anus (*a*).

FEMALE REPRODUCTIVE ORGANS.

PL. I.

The following is a description of the reproductive organs of the female of *Simulium venustum*. The two ovaries (*lo*, *ro*) are situated laterad of the ileum (*i*). They are small pear-shaped organs, transparent and composed of a thin outer membrane which forms a sack. The interior is filled in newly emerged adults with many small nuclear eggs. (Pl. I, fig. 1.) Joining the ovaries to the diverticulum and the basal membrane of the outer skeleton of the abdomen are large tracheæ, which branch many times, finally ending in thin threads. The caudal end of each ovary narrows into a tubular oviduct (*od*). The two oviducts join and form the cephalic end of the tubelike structure known as the utero-vagina (*v*). The utero-vagina and oviducts lie immediately above the lower end of the rectum. Leading from the cephalic end of the utero-vagina on the right side is a very narrow tube which terminates in a round, bulb-like structure, black in color, with a transparent membrane. This is the spermathecum (*s*), whose function is that of a reservoir for the spermatozoa injected by the male at the time of copulation. When an egg is deposited fertilization is effected as the egg passes the orifice in the spermathecum.

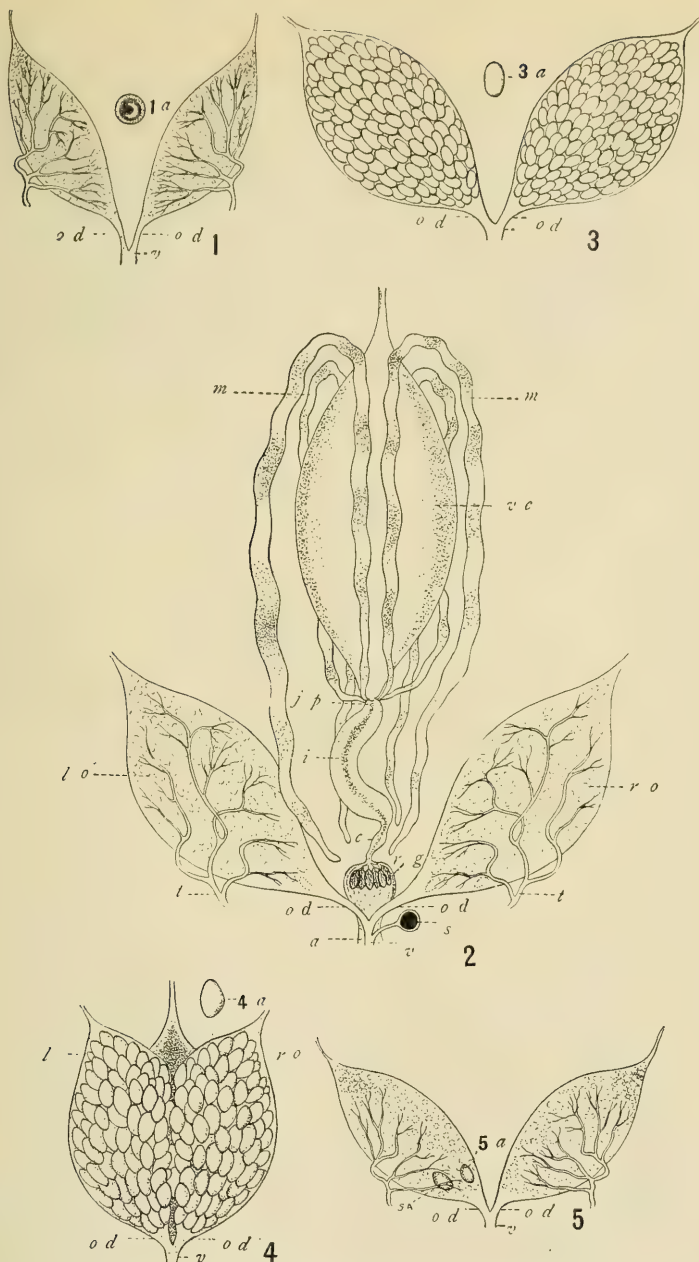
DEVELOPMENT OF THE EGGS.

The stages in the development of the eggs within the ovaries may be described at five different stages, as follows:

First stage.—The eggs are round, very small, rather transparent, and are present in the ovary in large numbers. As a rule they are rather indistinct. (Pl. I, fig. 1.)

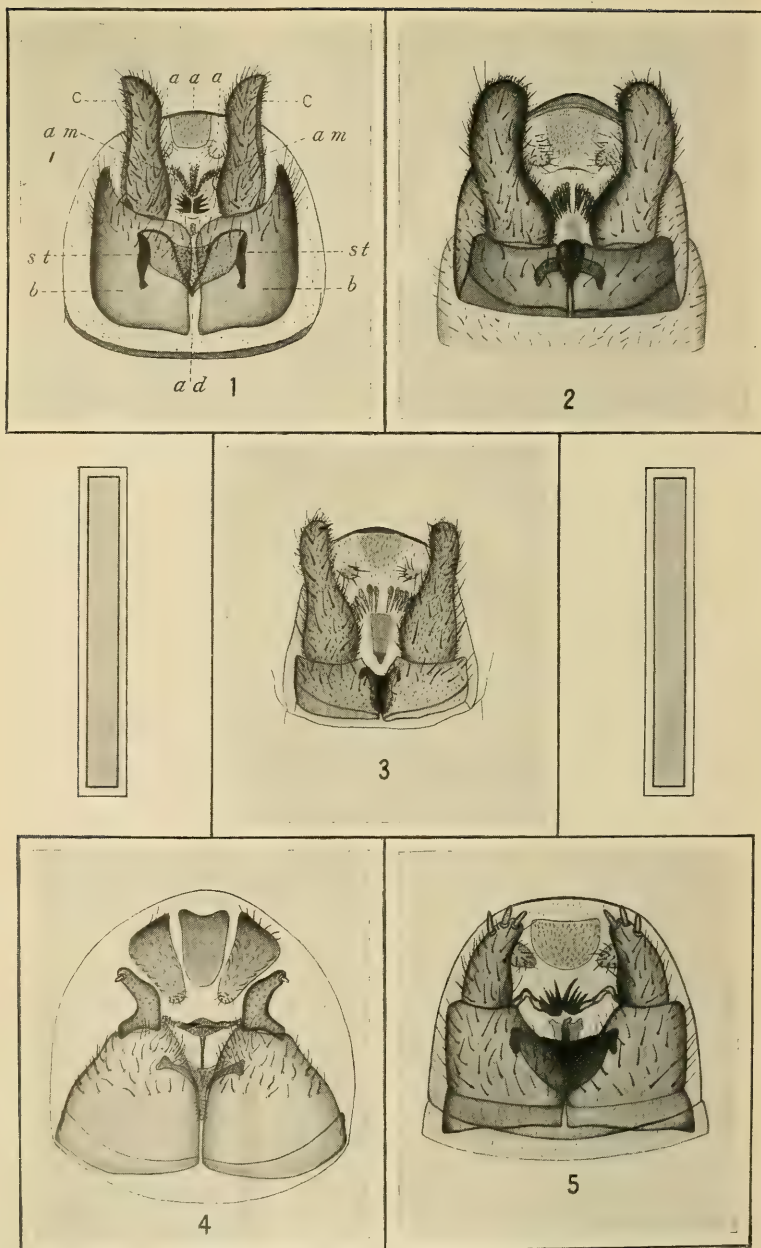
Second stage.—The eggs become denser and generally larger toward the oviduct, more irregular in shape with a tendency toward an oval form. As a rule they are still somewhat indistinct. (Pl. I, fig. 2.)

Third stage.—The eggs are of a perfect oval shape, dense as a rule, and of nearly equal development, those near the oviduct possibly larger. These latter have a tendency toward a slight bulge on one side. The shell has become somewhat denser in appearance, and the eggs on the whole are very distinct. (Pl. I, fig. 3.)



DEVELOPMENT OF EGGS WITHIN THE OVARIES OF *SIMULIUM VENUSTUM* AFTER A BLOOD MEAL.

FIG. 1.—Condition of ovaries corresponding to stage 1 (without feeding); 1a, single egg from same, larger scale. FIG. 2.—Condition of ovaries corresponding to stage 2 (after blood meal); also internal anatomy of abdomen; *ve*, ventriculus or stomach; *m*, *m*, Malpighian tubes; *jp*, juncture of Malpighian tubes and location of pyloric valve; *i*, ileum; *c*, colon; *rg*, rectal glands; *od*, *od*, oviducts; *a*, anus; *v*, vagina; *s*, spermathecum; *lo*, left ovary; *ro*, right ovary; *t*, *t*, tracheæ. FIG. 3.—Condition of ovaries corresponding to stage 3 (after blood meal); 3a, single egg from same, larger scale. FIG. 4.—Condition of ovaries corresponding to stage 4 (after blood meal); 4a, single egg from same, larger scale. FIG. 5.—Condition of ovaries after oviposition; 5a, large, fully developed eggs left near oviducts; remainder of ovary corresponding to stage 1. Highly magnified. (Original.)



MALE GENITALIA OF SIMULIUM.

FIG. 1.—Genitalia of male *Simulium pictipes*: *c*, *c*, Claspers; *a*, *a*, *a*, anal plates; *am*, *am*, arms; *b*, *b*, basal pieces; *st*, *st*, styli; *ad*, aduniculum. FIG. 2.—Genitalia of male *Simulium venustum*. FIG. 3.—Genitalia of male *Simulium jenningsi*. FIG. 4.—Genitalia of male *Simulium bracteatum*. FIG. 5.—Genitalia of male *Simulium vittatum*. All greatly enlarged. (Original.)

Fourth stage.—The eggs are fully as large as those newly laid on grass blades, of the same triangular form, very dense, the shell very strong, and not differing from eggs just laid, with the exception that occasionally they may be slightly smaller. (Pl. I, fig. 4.)

Fifth stage.—One or two large eggs are usually left in the ovaries near the oviduct, and the rest of the ovary is entirely filled with the typical round eggs of the first stage. This stage is found after adults have finished ovipositing, and also in specimens taken actually engorging, concerning which more will be said later. (Pl. I, fig. 5.)

THE GENITALIA OF THE MALE.

Pl. II, figs. 1-5.

The structure of the genitalia of the male shows remarkably constant specific characters. Their systematic value may be seen from the striking differences in the illustration. The determination of the species based on color alone is at best unsatisfactory owing to the amount of variation in individuals of the same species and fading of color in dry mounted specimens. The appearance of the structure of the genitalia does not change when the specimens are preserved in alcohol, and in dried specimens the original shape can be completely restored by the following method:

The last segment of the abdomen of the male after being removed with sharp scalpel or needle is placed in 6 per cent potassium hydroxid (KOH) and left until the soft parts are removed, the chitinous portions remaining intact. The material is then washed with water, run through alcohol in the usual way up to 100 per cent, transferred to xylol, and mounted in balsam, so as to give a direct caudal view as shown in Plate II, figures 1-5. Some of the European species have been studied in regard to the genitalia of the males by Lündstrom, but nothing has been done so far on American species.

The segments to which the organs of the genital armature are attached are collectively designated under the name hypopygium. The most prominent organs of the hypopygium are the two claspers (*c c*) and the basal pieces to which they are attached. The claspers may be either large, fingerlike, as in *S. venustum*, or greatly reduced and somewhat hook shaped as in *S. bracteatum*. They sometimes bear a spine at the distal end as in *S. venustum*, a single chitinous fingerlike process as in *S. bracteatum*, or three or four such processes as in *S. vittatum*. The basal pieces (*b, b*) to which the claspers are articulated are divided by a suture near the base. They are very large in *S. bracteatum* and are reduced in *S. venustum*. The relation between the size of the claspers and basal pieces seems to be very

constant. If the claspers are large the basal portion is much smaller in proportion, and vice versa.

There are three chitinous plates (*a, a, a*), which are situated toward the dorsal surface of the hypopygium and surround the anal orifice. The two lateral plates are generally armed with spines or stout hairs.

Ventrad of the plates and extending laterad on each side are two narrow chitinous flanges (*am, am*) bearing mesally groups of strong spines, sometimes in a large number as in *S. venustum* and sometimes reduced to only two as in *S. bracteatum*. These structures have been termed by Lündstrom the "arms." Ventrad of these spines and not easily distinguishable, extending inwardly, is a long, weak, chitinous piece, apparently the sheath of the penis. Ventrad and in front of this piece is a triangular troughlike sclerite called the adminiculum (*ad*), which is attached to two strong chitinous arms (*st, st*), termed by Lündstrom the stylus.

HABITS OF THE ADULTS.

COPULATION.

The writer has found adults in copula flying near the stream from which they were emerging, but they at once separated on being disturbed. Dr. Sambon informed the writer that in Italy he has found the males resting on the reeds in swarms, apparently waiting for the females to emerge.

DISPERSION.

It has been stated by several writers that the females travel long distances in search of food, but whether they are prompted by a desire for blood or are involuntarily carried away by the wind is a matter difficult to determine.

The writer has been severely bitten by the females of *S. johannseni* Malloch and *S. forbesi* Malloch in the sand-dune region of Havana, Ill., at a distance of 5 and even 6 miles from the only possible breeding place, which was the Illinois River. The fact that the adults crossed a bare and sandy waste with little or no wind, and that no males were present, seems to indicate that their flight was voluntary. Riley says that they may be carried 30 or 40 miles. They are sometimes attracted to light, as the writer has found a few specimens flying around a lamp at night.

FEEDING HABITS.

The adult female flies of all the species discussed in this paper, with the single exception of *S. pictipes*,¹ have been frequently observed feeding on the blood of mammals and, so far as the writer

¹ One female of this species, fully engorged with blood, was taken from a mule's ear by Mr. A. H. Jennings at Spartanburg, S. C., in 1912.

has observed, are limited to this diet. There are only two definite records to the writer's knowledge of *Simulium* feeding upon anything other than the blood of mammals. One is by Hagen (1883), who states that he found *Simulium* attacking and feeding upon the chrysalids of a butterfly (*Pieris*) *Neophasia menapia* Felder. He does not, however, state the exact species which he found so doing, and remarks that it was similar to the New England "black fly." The other record is by H. Pryer,¹ who states that in Japan he found *Simulium* attacking the larva of a sphingid, *Smerinthus planus* Walk., and also the imago of *Stauropus persimilis* Butl.

A detailed study was made by the writer in the region of Spartanburg, S. C., of the feeding habits of *Simulium venustum*, which was found from early spring to late fall engorging within the ears of horses and mules. Though invariably present on these animals, they were seldom found on cattle or on man. The severity of the attacks of this species depend both upon the time of year and the time of day. It is generally believed that the worst attacks occur in early spring and in early fall, and the writer found adults more numerous during the first three weeks of September than they had been since the middle of June. They appear to be most active from 3 p. m. to almost dusk. They are rather easily disturbed while feeding, and unless much distended will struggle violently to disengage themselves from the long hairs in the interior of the mules' ears. It has been noticed repeatedly that even the well-engorged specimens will retract their beaks and successfully fly away and not fall to the ground and crawl away to die, as has heretofore been claimed by certain writers. The fact that they are so easily disturbed and bite only under certain conditions probably accounts for the failure thus far of all efforts to get them to engorge while in captivity. While confined on the human body in a vial they make frantic efforts to escape and after 20 minutes become so exhausted as finally to remain on their backs with scarcely a sign of life. Whether the vial was covered to exclude the light or not, these experiments were unsuccessful at any time of day, both with reared specimens and captured ones. When placed in jars containing cloth saturated with defibrinated cow's blood a few took a small amount of blood into the crop, but there was no distension of the abdomen.

OVIPOSITION.

In the method of oviposition the different species of *Simulium*, whose life history has been studied in detail, show characteristic adaptations according to their habitat, and may be classified arbitrarily into two distinct groups. Although this grouping applies clearly to conditions in South Carolina, it is possible that exceptions may be found in other regions.

¹ See Bibliography, p. 35.

GROUP 1.

Group 1 contains species normally restricted to rivers which have rocky beds and such obstructions as bridge piles, piers, and, in time of floods, partly submerged trees. These species deposit their eggs at the level of the water, or just below, on any convenient surface, such as the bare portions of rocks, sunken posts, and collections of water-worn débris, always where the current is exceedingly swift. Eggs have never been found by the writer on any surface that was not smooth or that was at all covered by moss, algæ, or other aquatic growths. Of the five species whose methods of oviposition are discussed in this article, *S. pictipes* alone belongs in this group. The oviposition and early life history of this species were first described by Dr. W. S. Barnard in the American Entomologist in 1880. He states that the eggs are long ovoid in form, and gives a figure showing them deposited in a vertical position. He also states that the young larvæ were issuing from the eggs deposited on the rocks above the water line and were passing down into the water to begin aquatic life. If this was the case, the eggs must have been moistened continually by the spray and not left in a dry state, as is implied, the reason for which surmise will be discussed at length farther on.

The eggs of this species which were found by the writer seemed to have been deposited indiscriminately in a horizontal as well as in a vertical position. The angles appeared rather broadly rounded. (Pl. III, fig. 6.) Surrounded by a viscous substance known as the matrix, in which they are fairly evenly distributed, they are laid normally in masses on the smooth surface of the rocks just below the level of the water. The matrix is brownish yellow at first, afterwards turning brown. Usually several females will oviposit in the same spot, causing the layers to overlap.

GROUP 2.

Group 2 is made up of species which are peculiar to small streams with less force of current and with only submerged herbage or occasional small collections of sticks and stones to serve as a place for the attachment of the immature stages. As a general rule the situation selected for oviposition is a grass blade bent at right angles and trailing just at the surface of the water and with its surface continuously moistened.

S. vittatum almost invariably oviposits on grass blades in small streams. The eggs adhere to the grass blades by a creamy viscous matrix entirely covering the eggs. This matrix turns yellowish brown on the second day and becomes gradually darker until the eggs hatch. The eggs are laid in a single layer, as a rule, very closely together. Several females often select the same situation and, as in the case of *pictipes*, the layers often overlap one another.

At Dallas, Tex., in March, 1913, *S. vittatum* was found by the writer ovipositing in considerable numbers on the small stones in the limestone bed of a small stream which was almost devoid of submerged herbage. The eggs were laid generally below or at the surface of the water. In a few instances they were found an inch or so above the water, but this was owing to a decrease in the amount of water, which varies considerably in this and the majority of streams in Texas. This species has been found by the writer on one occasion at Havana, Ill., ovipositing in large numbers on the bridge piles in the Illinois River. The eggs were deposited at or just below the level of the water, and as the river was falling at the time at the rate of an inch a day, the eggs underwent complete desiccation, and all were destroyed. The bridge piles were literally covered with the matrix and eggs, and many females, becoming entangled, died adhering to the viscous masses. This oviposition of this species in the main river seems to have been an abnormal occurrence, as the larvae have never been found in this situation. Another species, however, *S. johannseni*, according to the writer's observations, breeds in enormous numbers in the main channel in the spring, around the submerged vegetation near the banks and wherever there is an obstruction.

S. venustum, in the regions studied, belongs entirely to group 2. The eggs are laid on submerged grass blades and the like in small streams, in situations similar to those selected by *S. vittatum*. The eggs are more evenly arranged than those of that species, the matrix is not smeared so profusely, and the egg mass is generally oblong in shape and very compact. This species has many times been observed ovipositing, and specimens which subsequently laid a full quota of eggs in captivity were taken from the stream as they alighted.

The oviposition in captivity of *S. venustum* was observed by the writer at Spartanburg, S. C., on September 16, 1913. A female *S. venustum* was noticed at 5.08 p. m. moving up and down a small stream within a space of about 4 feet, apparently seeking a suitable place for oviposition. She would touch the water for an instant and then, apparently dissatisfied, fly up again. This peculiar interrupted flight was continued for a period of two minutes, after which she alighted on a grass blade which seemed to be satisfactory. Immediately a bottle was placed over her and she was at once taken to the laboratory. The stream from which the specimen was taken was situated 50 yards from the laboratory, and thus little time was lost in transit. The bottle in which the specimen was taken was partly wet inside. At 5.13 p. m., as soon as the bottle was placed on its side, she felt around for two minutes and then settled into position, rapidly thrust out the end of her abdomen, and deposited an

egg about every two seconds, as fast as she could extend and retract her ovipositor. Ten eggs were laid in a sort of half circle and then the intervening space was filled up until each egg touched another. In addition a few were laid a short distance away and the intervening space filled up. Oviposition continued steadily until 5.20 p. m., when, she stopped, turned around, felt the mass with her feet, and commenced again. She stopped at 5.21 for 30 seconds and cleaned the end of her abdomen. Another lot of eggs was then laid a little farther off, in a long, irregular row, about five eggs wide. Oviposition was finally ended at 5.27.30 p. m.

She seemed always to feel for a suitable place before ovipositing. A dry spot was invariably rejected. One hundred and forty-five eggs were laid from 5.15 to 5.20, about 80 eggs from 5.20 to 5.21 (this seemed to be the maximum rate of oviposition), and about 117 from 5.21 to 5.27.30. The total number of eggs laid was 349. As there were two interruptions, one at 5.20 for three seconds and one at 5.21 for 30 seconds, the length of time spent in oviposition was 12 minutes. The average rate at which the eggs were laid, therefore, was about one every two seconds.

The abdomen was dissected, and only one developed egg was found. This was in the oviduct, showing that the oviposition was normal, as all developed eggs, with this exception, had been deposited.

S. bracteatum seems to be entirely restricted to the smaller streams, and its method of oviposition is similar to that of *S. venustum* in all respects. It is of the same size as *venustum* and deposits about the same number of eggs at one oviposition.

S. jenningsi is so closely allied to *S. venustum* that it is extremely difficult to distinguish the egg masses of the two species, the main points of difference being the smaller size of the *S. jenningsi* mass and the somewhat smaller number of eggs that are deposited.

The time of day generally chosen for oviposition by these five species of *Simulium* is from about 4.30 p. m. to 5.30 p. m., or even until dusk. The weather conditions most favorable seem to be sunshine and lack of wind. Females have been found ovipositing at a maximum water temperature of about 95° F. The earliest records of oviposition were made by the writer at Dallas, Tex. (latitude 32° 4' 8''), on March 25, and the latest at Spartanburg, S. C. (latitude 34° 50''), on November 2.

There have been various estimates given by authors, both in Europe and America, upon the number of eggs laid by *Simulium*. The number of eggs stated to have been laid, or probably laid at one oviposition by a single female, varies from 500 to 1,500. This latter figure, given for the European species *S. reptans* L. (*S. columba-*

schense Fab.), is probably erroneous, as the species is very like *S. venustum* in size and structure. It is the opinion of the writer, from many observations, that the largest possible number of eggs which are deposited at one time by a single female can not exceed 500.

The question whether eggs of *Simulium* can be subjected to desiccation and then hatch after being immersed again in water is of interest, as it has been suggested that in the more or less torrential streams found in Texas and the Western States, which flow only a few months in the year, the eggs might remain in a dry condition during the summer and hatch in the fall or spring with the rising of the water. For this reason experiments have been made by the writer to ascertain whether *Simulium* eggs, after partial or complete desiccation, would hatch on being again placed in water, as is the case with some species of mosquitoes. These experiments all showed that at Spartanburg, S. C., the contents of freshly laid eggs became completely disintegrated after being thoroughly dried, and that when the eggs contained embryos, the latter became distorted on the second day after removal from the water, and though they were replaced in running water after that period the contents of all finally disintegrated without a single egg hatching.

When eggs are found at any distance above the water line, the writer believes investigation will show that a fall in the water level has occurred. The great outbreaks of *Simulium* in the large rivers during the early spring are due primarily to the fact that the rising water submerges the growth on the banks and that the water either rises or remains at the same level throughout that period, thus preventing desiccation of the eggs.

THE EGG STAGE.

The eggs of *Simulium* are usually rather triangular in shape, with the angles broadly rounded. (Pl. III, figs. 1-5.) The egg of *S. pictipes* (Pl. III, fig. 6), however, is more ovoid in shape than that of the four other species dealt with in this paper. The shell, which is very tough and apparently somewhat chitinous, withstands the action of the water for a considerable period without disintegrating, and has been found by the writer in a good state of preservation after six weeks in this element.

The color of the egg when first laid (Pl. III, fig. 1) is opaque white, which changes to yellowish brown as the development of the embryo proceeds. The interior of the newly laid egg appears to be an even mass of yolk substance. When the egg contains a half-developed embryo the yolk substance seems to be consolidated into a central mass, indented at both extremities and surrounded by layers of

closely arranged cells (Pl. III, fig. 2). The interior of an egg containing an embryo three-fourths developed has a peculiar banded appearance (Pl. III, figs. 3, 4), but as the time of hatching approaches the most noticeable features are the cephalic eye spots on the embryonic larva, which become more and more distinct. (Pl. III, fig. 5.) Detailed studies on the embryology of *Simulium* have been made by Mecznirow,¹ Kölliker,¹ and Graber.¹

The average period of incubation, from June to October, of the species studied by the writer at Spartanburg, S. C., was about 8.8 days; the minimum period, 7 days; and the maximum, 12 days. The following table will show the normal variation in that region from June to October:

Table showing period of incubation of eggs of Simulium.^a

Lot No.	Species.	Date of oviposition.	Number of days of incubation.													
			1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	<i>S. venustum</i>	June 12	a	a	a	b	b	c	c	d	d	h	h	.....	.....	.....
2	<i>S. vittatum</i>	June 21	a	a	a	b	b	c	c	d	d	h	h	.....	.....	.....
3	do.....	July 23	a	a	a	b	b	c	c	d	d	h	h	h	h	.....
4	<i>S. bracteatum</i>	Sept. 6	a	a	a	b	b	c	c	d	d	h	h	.....	.....	.....
5	do.....	Sept. 11	a	a	a	a	a	b	b	b	c	c	d	h	.....	.....
6	<i>S. venustum</i>	Sept. 16	a	a	b	b	c	c	c	d	h	.....	.....	.....	.....	.....
7	do.....	do.....	a	a	b	b	b	c	c	d	h	.....	.....	.....	.....	.....
8	do.....	do.....	a	a	b	b	c	c	c	d	h	.....	.....	.....	.....	.....
9	do.....	do.....	a	a	b	b	c	c	c	d	h	.....	.....	.....	.....	.....
10	do.....	do.....	a	a	b	b	c	c	c	d	h	.....	.....	.....	.....	.....
11	do.....	do.....	a	a	b	b	c	c	c	d	h	.....	.....	.....	.....	.....
12	do.....	do.....	a	a	b	b	c	c	c	d	h	.....	.....	.....	.....	.....
13	do.....	do.....	a	a	b	c	c	c	d	d	h	h	h	.....	.....	.....
14	do.....	do.....	a	a	b	c	c	c	d	d	h	h	h	h	.....	.....
15	do.....	do.....	a	a	b	c	c	c	d	d	h	h	h	h	h	.....

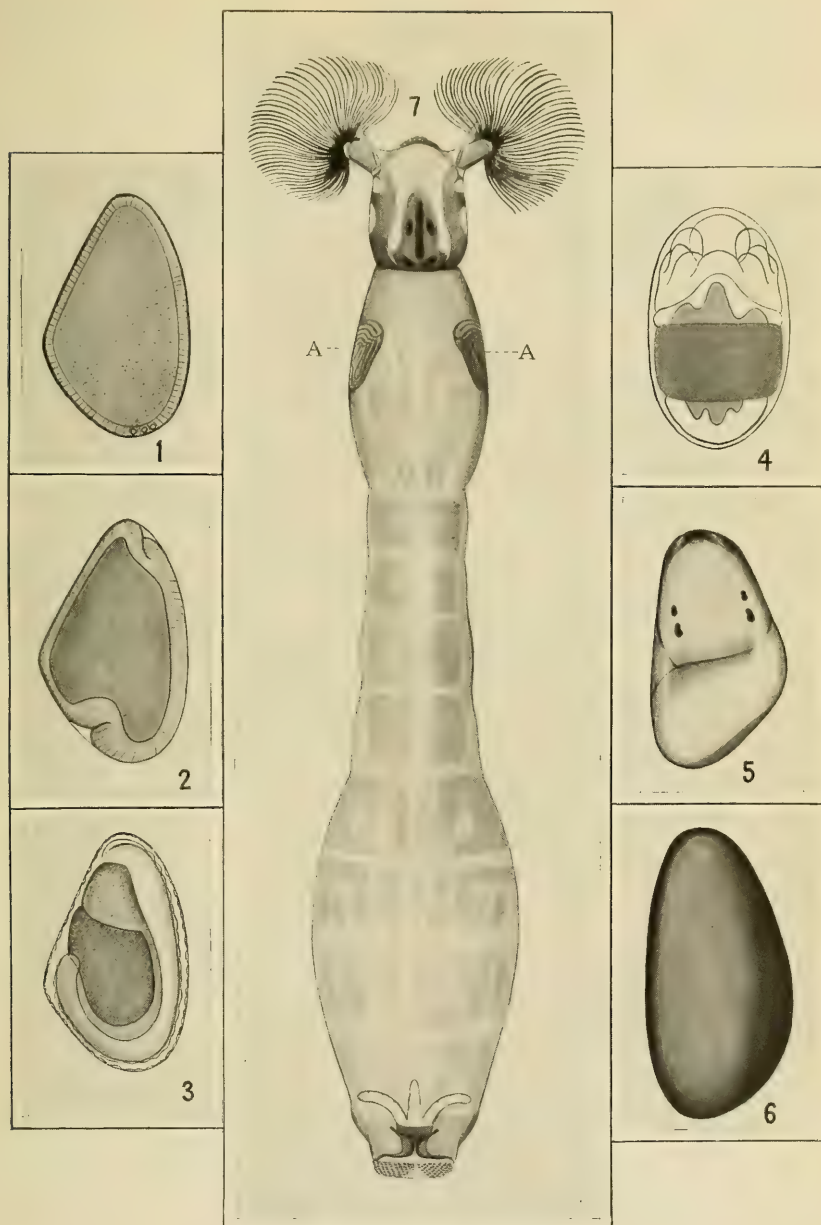
^a Letters indicate stage of incubation, shown on Plate I, as follows: a, corresponds to fig. 1; b, corresponds to fig. 2; c, corresponds to figs. 3, 4; d, corresponds to fig. 5; h, date of hatching.

The eggs seem to hatch equally well in either still or running water. The percentage of eggs that hatch is very high when they are placed so that the water reaches them, the average sterility of a series of lots kept under observation in normal conditions being from 4 to 5 per cent. The approximate percentage of egg masses, however, that is deposited under such favorable conditions is certainly relatively small as compared with the total number deposited, and the location of the egg mass seems to be the dominant factor in determining the successful hatching of the larva and the consequent abundance of the insect.

THE LARVAL STAGE.

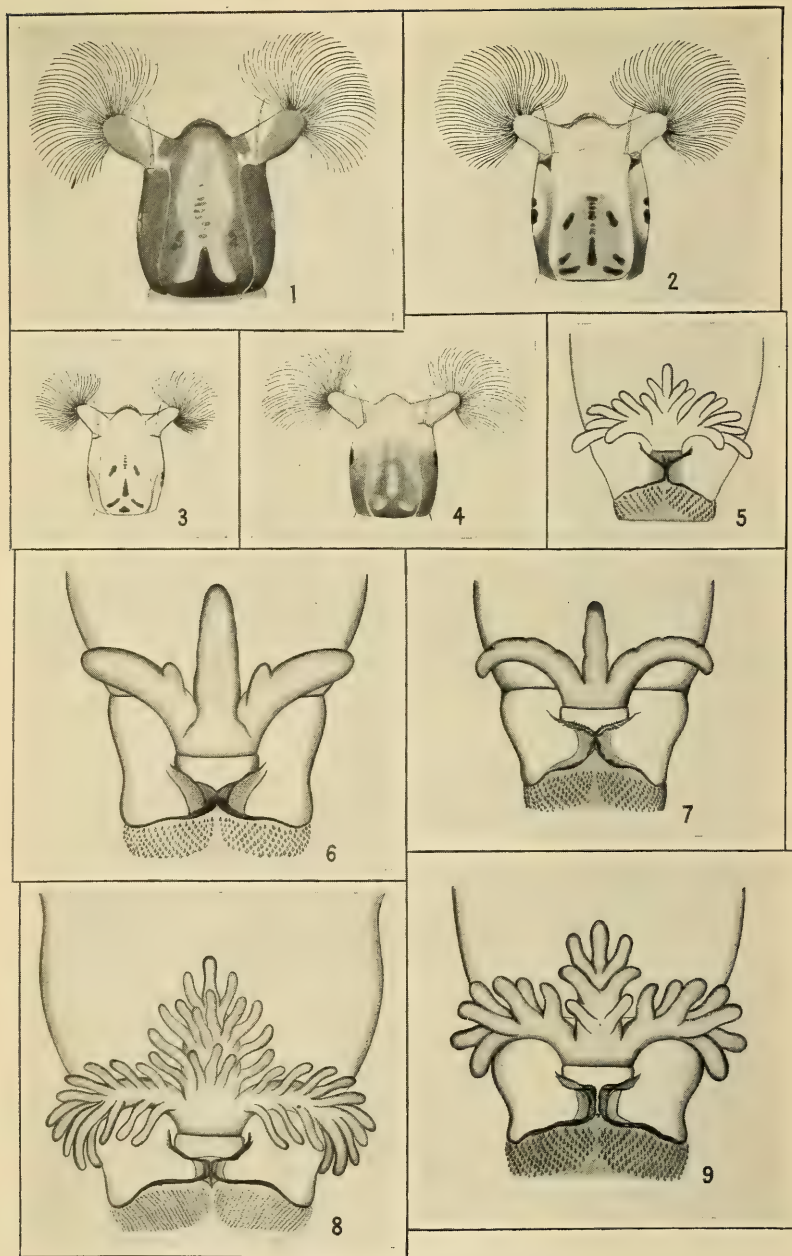
The larvæ of the known species of *Simulium*, as will be discussed at length farther on, are invariably aquatic in their habits and re-

¹ See Bibliography, p. 35.



EGGS AND LARVA OF SIMULIUM.

FIG. 1.—Egg of *Simulium venustum*, freshly laid. (After Mecznicow.) FIG. 2.—Egg of *Simulium venustum*, second to fourth day. (After Mecznicow.) FIG. 3.—Egg of *Simulium venustum*, fourth to sixth day, showing "banded appearance." (After Mecznicow.) FIG. 4.—Same, dorsal view. (After Kölliker.) FIG. 5.—Egg of *Simulium venustum*, just before hatching, showing larva in a free condition within the shell. (Original.) FIG. 6.—Egg of *Simulium pictipes*. (Original.) FIG. 7.—Larva of *Simulium bracteatum*, showing histoblasts of pupal filaments, A, A. All greatly enlarged. (Original.)



HEADS AND RECTAL GILLS OF SIMULIUM LARVÆ.

FIG. 1.—Head of larva of *Simulium pictipes*. FIG. 2.—Head of larva of *Simulium vittatum*. FIG. 3.—Head of larva of *Simulium jenningsi*. FIG. 4.—Head of larva of *Simulium venustum*. FIG. 5.—Rectal gills of larva of *Simulium jenningsi*, typical form. FIG. 6.—Rectal gills of larva of *Simulium vittatum*, variety with small lobes at base. FIG. 7.—Rectal gills of larva of *Simulium bracteatum*, typical form. FIG. 8.—Rectal gills of larva of *Simulium pictipes*, typical form. FIG. 9.—Rectal gills of larva of *Simulium venustum*, typical form. All greatly enlarged. (Original.)

quire swiftly flowing water for their development. The full-grown larva of the largest species, according to Johannsen, measures not more than 15 mm. in length. The American species known to the writer measure from 12 mm. (*S. pictipes*) to 3.5 mm. (*S. jenningsi*). The larvæ are generally subcylindrical, somewhat attenuated at the middle, and with a gradual dilation toward the anal extremity. In addition to the head there are 12 rather indistinct body segments.

In the larval stage the shape and number of the branches of the rectal gills seem to be good systematic characters, not differing essentially among individuals of the same species. If the number and

length of the antennal joints, the teeth in the mentum, and the character of the dorsal markings of the head are also used, the determination of half-grown

larvæ is possible. The larvæ in their last stage can be correlated positively with their respective pupæ by the dissection and study of the pupal filaments, which become fully developed under the larval skin.

As the larvæ of *S. bracteatum* and *S. jenningsi* have not been previously described, the following descriptions are given.

DESCRIPTION OF LARVA OF SIMULIUM BRACTEATUM.

The full-grown larva is from 6 to 6.5 mm. in length. The general color varies from light yellowish-brown to grayish, with conspicuous brownish markings on the ventral surface. The antennæ (fig. 3) are slender, 4-segmented;¹ the second segment one and one-half times as long as the first; the third segment as long as the first; the fourth a short conical process; the general color pale hyaline; the first segment infusate.

The labial plate (fig. 4) is more strongly serrate than that of *S. venustum* (fig. 5): the apical margin rather convex; the middle tooth and each corner tooth very large. There are from four to five long bristles near the lateral margin on each side.

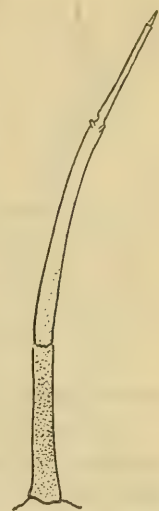


FIG. 3.—*Simulium bracteatum*. Antenna of larva. Greatly enlarged. (Original.)

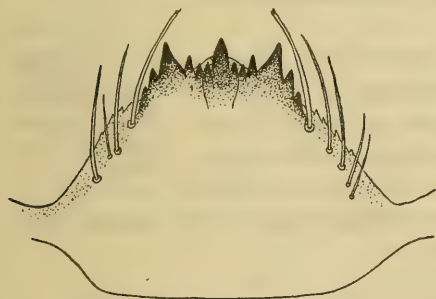


FIG. 4.—*Simulium bracteatum*. Labial plate of larva. Greatly enlarged. (Original.)

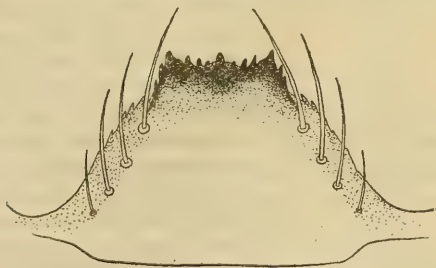


FIG. 5.—*Simulium venustum*. Labial plate of larva. Greatly enlarged. (Original.)

¹ The writer differs from other writers in regard to the segmentation of the antennæ.

The head (Pl. III, fig. 7) is light brownish-yellow in color, heavily marked with brown on the lateral margins. The dorsal markings of the head are arranged in the form of a long central irregular blotch, with two adjacent blotches extending diagonally on either side.



FIG. 6.—*Simulium bracteatum*. Row of spines from caudal sucker of larva. Greatly enlarged. (Original.)

The mandibles are similar to those of *S. venustum* (fig. 12), but darker in color. The maxillæ are infusate and very hairy; the proximal portion of the maxillary palpus is dark brown, with a few sparse hairs; the distal end transparent, bearing a few conical processes.

The rectal gills (Pl. IV, fig. 7) are simple, three branched, somewhat pointed toward the distal end, and are curved backward cephalically when extended.

The caudal sucker bears from 60 to 70 rows of spines or hooks (fig. 6).

The larvæ were taken by the writer from several streams in the vicinity of Spartanburg, S. C., from June to October, 1913. They were separated from the larvæ of other species by the number of the branches of the pupal filaments (formed underneath the larval skin) and determined from adults reared from them and compared with the type.



FIG. 7.—*Simulium jenningsi*. Antenna of larva. Greatly enlarged. (Original.)

DESCRIPTION OF THE LARVA OF SIMULIUM JENNINGSI.

The larva of *Simulium jenningsi* is much smaller than that of *S. venustum* and measures from 3.5 to 4.5 mm. in length. The general color is light brownish yellow. The head is of a uniform yellow with dark-brown blotches of characteristic arrangement on its dorsal surface (Pl. IV, fig. 3), thus differing from *venustum* (Pl. IV, fig. 4), which usually has the pigment in these cells lacking. The antennæ (fig. 7) are slender and 4-segmented, the last segment being a short conical process; the first three segments are subequal in this species, while the antennæ of *venustum* (fig. 8) have the second segment longer than the first. The labial plate (fig. 9) is broader than that of *venustum* (fig. 5) the teeth more even and equal in size, the middle tooth not very prominent, and there are apparently only two large and one small bristle along



FIG. 8.—*Simulium venustum*. Antenna of larva. Greatly enlarged. (Original.)

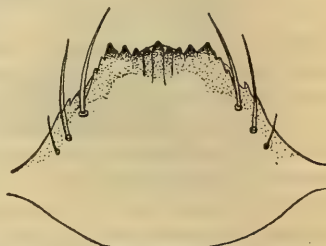


FIG. 9.—*Simulium jenningsi*. Labial plate of larva. Greatly enlarged. (Original.)

each margin, while *venustum* has four to five large bristles on each side. The mandibles are of the usual type, but rather weak and the teeth somewhat pale.

The rectal gills (Pl. IV, fig. 5) are three-branched, each lateral branch bearing six lobes and the middle branch five, as a rule. This is a smaller number of lobes than is found in *venustum* (Pl. IV, fig. 9), which has seven or eight on each lateral branch.

The caudal sucker bears from 70 to 75 rows of hooks.

The larvæ were taken by the writer from a fair-sized stream near Spartanburg, S. C., in August, 1913, and were separated from the larvæ of other species by the number of branches of the pupal filaments (formed underneath the larval skin) and determined from adults reared from them and compared with the type.

EXTERNAL AND INTERNAL STRUCTURES OF THE LARVÆ.

The head is more or less quadrangular in shape and very chitinous. The eyes have become reduced to mere pigment cells, in the shape of two irregular black blotches, situated on each side of the head.

In addition to the usual mouth parts, the head bears a pair of peculiar fan-like organs, situated one on each side at the anterior end. The rays or cilia of the fans are attached at the base each by a strong peduncle and range in number from 30 to 60 according to the species. On the inner margin of these cilia are fringes of short hairs interspersed with minute teeth. As the number of cilia varies in individuals of the same species, they are not very reliable specific characters. The fans, acting as strainers, catch the microorganisms on which the larvæ feed and sweep them into the mouth.



FIG. 11.—*Simulium vittatum*. Antenna of larva. Greatly enlarged. (Original.)



FIG. 10.—*Simulium pictipes*. Antenna of larva. Greatly enlarged. (Original.)

The antennæ (figs. 3, 7, 8, 10, 11) are situated at the sides of the head, on the dorsal surface toward the cephalic end, just below the base of the fans. They are slender, and in the species examined, naked. Johannsen says "The antennæ are apparently jointed * * * the first joint twice as long as the others taken together; the second, slender cylindric * * * the third joint a short pointed process at the apex of the second." Miall says "Small three-jointed antennæ" and gives a figure in which the antennæ have three long joints and lack the short pointed process forming the last joint. Of the five species dealt with in this paper, the larvæ of *Simulium venustum* (fig. 8), *S. pictipes* (fig. 10), and *S. bracteatum* (fig. 3)

have the antennæ 4-jointed, the first long joint described by Johannsen being divided by a very distinct suture. Though the first and second joints are very closely articulated and rigid, the constant occurrence of a distinct suture between them seems to indicate clearly the existence of two segments. The third segment is slender cylindrical, and the fourth a short conical process.

There are two conical processes situated at the apical end of the second segment, which seem to be sense organs. The antennæ of *S. vittatum* (fig. 11) are 5-segmented, the second segment being again divided. The sense organs are borne on the apical end of the third segment. In color the antennæ vary with the species from yellowish hyaline to dark brown.

The mandibles are situated just below the fans and move horizontally. With the exception of a slight difference in size, according to the species, there are no constant characters of real systematic value in the mandibles.

The following is a description of the mandibles of *S. venustum*:



FIG. 12.—*Simulium venustum*.
Left mandible of larva, ventral view. Greatly enlarged.
(Original.)

The mandibles (fig. 12) are very chitinous, stout, somewhat elongate, with the outer lateral margin rounded. There are from two to four large teeth at the apex on the inner lateral margin, almost dense black in color. Situated immediately dorsad along the inner margin of the largest tooth is a row of from six to eight smaller teeth of the same shape, but much lighter in color and gradually decreasing in size.

Behind this row, on the ventral surface of the mandible, arising generally from the third or fourth tooth, is a second row of small, sharp-pointed teeth very pale in color, about 10 to 14 in number, which continues along the basal portion of the lateral margin of the largest apical tooth. Laterad of this second row of teeth, on the inner margin of the mandibles, there is a large wide-angled flattened tooth, very pale in color, followed by a smaller one of the same description. Near the apex of the mandible, a short distance from the outer lateral margin of the ventral surface, are two large bristles arising from almost the same point. At the base of the large apical teeth, on the ventral surface, are two clumps of stout hairs. There is a fringe of long hairs on the dorsal surface of the mandible, which extends halfway down, commencing at the apex, where it almost obscures the apical teeth. Opposite the base of this fringe on the inner lateral margin of the mandible there is a fan of long hairs, and a fringe of very long hairs, which continues down to the base, gradually developing into bristles explanate and divided at apex.

The maxillæ are situated immediately ventrad and mesad of the mandibles. The maxillary palpus is short, cylindrical, and bears on its distal end several small cone-shaped protuberances similar to

those borne on the third segment of the antenna. The lacinia bears mesad and cephalad fringes of long hairs and bristles. On its distal end there is a single spurlike process.

The labrum is short, rounded, fringed with long hairs, and is situated overhanging the hypopharynx. It is reinforced on its dorsal surface by a strong T-shaped sclerite. The apical margin is sometimes serrate.

The labium (figs. 4, 5, 9, 13, 14), which almost covers the ventral surface of the hypopharynx, is composed of two or more broad chitinous united plates. It is immovable. The apical edge of the ventral plate is serrate.

The lateral and apical margins of the dorsal plate are also serrate and the apical margin usually bears a very prominent central tooth. In some species the teeth are trifid, and in others simple. There is a row of from three to 10 long bristles near each lateral margin of the ventral plate. The number and shape of the teeth and the arrangement of the bristles are of systematic value in separating the different species, and Robaud and Malloch¹ consider these char-

acters to be of possible generic value. There is a certain amount of individual variation, but seemingly within definite limitations.

The dorsal portion of the head in most species has distinct markings of very characteristic arrangement. (Pl. IV, figs. 1-4.) Though subject to a certain amount

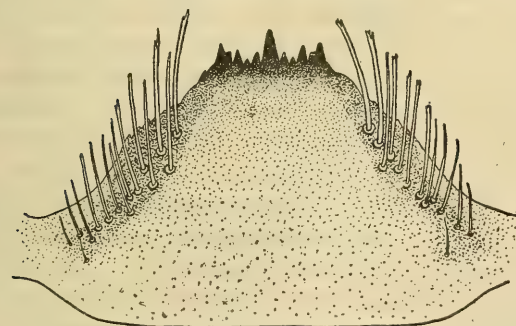


FIG. 14.—*Simulium pictipes*. Labial plate of larva. Greatly enlarged. (Original.)

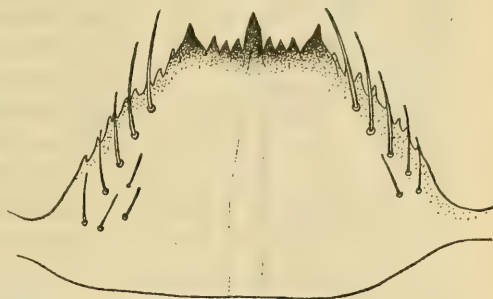


FIG. 13.—*Simulium vittatum*. Labial plate of larva. Greatly enlarged. (Original.)

of individual variation, they are of systematic value in separating the different species especially when combined with other more constant specific characters. These markings are formed by a collection of large cuticular cells which, in some species, such as *S. vittatum*, are strongly pigmented, while in others, such as *S. venustum*, they are normally almost devoid of pigment, the surrounding area being dark.

¹ Malloch, J. R. American black flies or buffalo gnats. U. S. Dept. Agr. Bur. Ent. Tech. Ser. no. 26, 71 p. (p. 8), 6 pl., 1914.

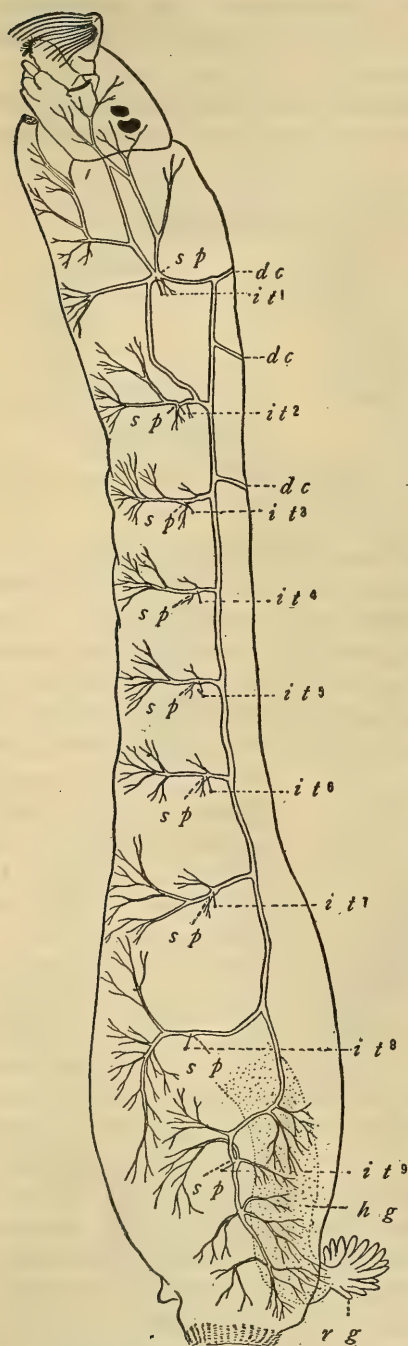


FIG. 15.—*Simulium venustum*. Tracheal system of larva: *dc*, *dc*, *dc*, Dorsal commissures; *it*, initial threads; *sp*(9), spiracular chambers; *hg*, hind gut; *rg*, rectal gills. Greatly enlarged. (Original.)

The thoracic proleg of *Simulium* larvæ consists of a single elongated, truncate process, attached to the second thoracic segment and bearing concentric rows of minute hooks at its apical end, which is cup-shaped, and capable of muscular contraction, thus forming a suckerlike organ, used by the larva as means of attaching itself. A somewhat similar but very much larger suckerlike disk is situated at the caudal extremity of the larva. The rim is composed of rows of strong chitinous hooks as in the proleg. The number of rows ranges in the different species from 50 to 140, and the number of hooks in a row from 8 to 30. There is so much individual variation in the number of rows and the number of hooks in a row that they are not of much systematic value. The average number of rows in the caudal disks of five species is as follows: *S. jenningsi*, from 70 to 75; *S. venustum*, from 55 to 65; *S. bracteatum*, from 60 to 70; *S. vittatum*, from 65 to 85; *S. pictipes*, from 130 to 140. *S. pictipes* has by far the greatest number of rows, very close together and from 25 to 30 hooks in each row. It is the only one of these five species that can be positively determined on these characters alone.

RESPIRATORY SYSTEM OF THE LARVÆ.

The tracheal system of the larva (fig. 15) consists of two main longitudinal trunks, connected by commissures, which lead to the spiracular chamber. Extending from the spiracular chambers are thin chitinous rods (the initial threads), which lead to the oval

thickenings of the cuticle known as the spiracles. The spiracles do not seem to be functional as a means of respiration.

Respiration apparently takes place by what are known as the rectal gills (Pl. I, fig. 2, *rg*), which are extensions of the rectal wall and are formed of the same epithelial layer. These extensions are primarily 3-branched, and are either simple or bear numerous lobes. Minute tracheolæ penetrate these gills, joining the main trunks at the base of the rectum. The gills are also filled with blood, are retractile into the rectum, but are usually extended in running water. According to Headlee, they function both as blood gills and as tracheal gills, as the presence of blood in them is undoubted, and since the tracheæ in them are very minute. The tracheal system can be seen very distinctly in living larvæ. Several larvæ, still quite active, were placed in a shallow dish of water and examined under the binocular by the aid of strong sunlight against a black background. As the larvæ slowly died the tracheæ, owing to the air collected in them, showed a bright silvery appearance, so that even the very small ramifications and branches could be clearly distinguished. The larvæ seem to be in a comatose condition an hour or so before death, and the silvery appearance of the tracheæ remains for about three hours after death, so that there is a considerable period in which the tracheæ may be studied before the air is driven out. In larvæ preserved in alcohol or mounted in balsam the air, of course, is driven out of the tracheæ, which becomes almost transparent, so that it is very difficult to trace them in this condition. The tracheæ become greatly ramified toward the caudal end of the body and seem to penetrate the wall of the alimentary tract and to extend into the rectal gills.

Larvæ have not been found to survive longer than forty-eight hours in still water, and on being transferred from flowing water will turn back constantly in an effort to clean the rectal gills with the mouth parts. Larvæ placed in still water and only barely covered will survive longer than those covered to a depth of 3 inches or more. That the lack of oxygen is responsible for the death of the larvæ transferred from flowing to still water is further evidenced by the fact that the larvæ will survive longer in a tightly corked bottle at a temperature of 32° F. than at a temperature of 75° F., because the amount of oxygen that can be held in solution by the water varies inversely as the temperature. Larvæ seem to thrive equally well in running water, whether the temperature is 32° or 75° F. Low temperature seems to retard but not to injure development, and a rising temperature up to 75° F. hastens development.

The structure of the rectal gills and the number of lobes afford excellent systematic and specific characters, as may be seen from the accompanying figures (Pl. IV, figs. 5-9). The variation in individuals seems to be bounded by well-defined limitations.

LARVAL DEVELOPMENT.

From 12 to 16 hours before hatching the young larvæ are in an apparently free condition within the shell. There is an almost continual movement of the head, which is forced against the ectoderm by sudden convulsive movements of the body. The shell suddenly splits and the larva at once emerges, literally tumbling out. The split reaches from the cephalic end of the egg to the middle, generally a little to the left. It is evident from the clear appearance of the alimentary tract of the newly emerged larva that the ectoderm is not eaten away at all. The larva at once clings to the nearest point of attachment by its thoracic proleg and waves its anal portion around several times, evidently to clear the rectal gills. It then attaches itself to the nearest object by the peculiar suckerlike organ on its anal extremity and thrusts out its gills at intervals of about 15 seconds. It at once commences to feed on the matrix surrounding the eggs and the adjacent microorganisms, using its thoracic proleg as a scoop, with a constant movement of this organ toward the mouth parts. In still water the fans are not used for sweeping in the food for some hours after the larvæ have hatched, but remain appressed to the sides of the head.

The newly hatched larvæ of all the species described in this paper measure from two-thirds to three-fourths of a millimeter in length. The structure of the larvæ in the first instar, of the species examined by the writer, is fundamentally the same as in the last, with the exception that the head is larger in proportion to the rest of the body and the general appearance very transparent, due to the lack of pigmentation and the empty condition of the alimentary tract. The black eye spots on the sides of the head are very prominent, and the dorsal markings of the head, though not so distinct as in later stages, are easily distinguishable. The silk glands are employed almost at once after hatching to form a silken thread, which is used to hold the larva in position in the current. The structure of the rectal gills seems to remain the same throughout larval development.

LARVAL HABITS.

MOLTING OF THE LARVÆ.

According to Strickland¹ the larvæ do not shed the entire skins but only the skeleton of the head. The writer has found that the entire skin is shed, as larvæ have been found which had partly cast off the entire skins, bearing the chitinous hooks of the caudal sucker, and which showed the caudal sucker again developed in the new larval skin. The entire skeleton of the head is cast off toward the

¹ Strickland, E. H. Some parasites of *Simulium* larvæ and their effects on the development of the host. (*In* Biol. Bul., v. 21, no. 5, p. 302-338 (p. 303), 5 pl., Boston, 1911.

front at molting, and the remainder of the skin toward the caudal extremity, the tracheæ being withdrawn through the spiracular openings. The number of molts has not been determined.

MIGRATORY HABITS AND LOCOMOTION OF THE LARVÆ.

On being suddenly disturbed or on the diminishing of the current, the larvæ let themselves be carried down stream steadied by the silken thread previously described, which they have attached to some stationary object, and seek a more favorable situation. In many instances the larvæ have been observed almost to regain their former position, by winding up the thread with the thoracic proleg and mouth parts, but as a rule they are unable to work against the current. The method of locomotion in still water is similar to that of geometrid larvæ. By looping the body, they bring the anal extremity forward beside the proleg, which is then released on the caudal sucker again obtaining a firm hold.

A heavy rain causing a sudden swiftening of the current will often entirely change the distribution of the larvæ. This fact is of considerable economic importance, as it may account for the sudden appearance of *Simulium* in localities usually exempt. This was well illustrated in the following instance, observed by the writer at Spartanburg, S. C. A fair-sized stream had been free from larvæ for two months or more, when one of the tributaries near its source became heavily infested with young and half-grown larvæ. A heavy rain and consequent washout carried practically every larva from the tributary down the large stream for nearly a mile, where they became successfully established, causing a subsequent heavy infestation.

Young larvæ seem to migrate more readily than full-grown larvæ. Several experiments were tried in regard to this. A vessel containing larvæ of all sizes was placed under a running faucet, causing the vessel to overflow. The full-grown larvæ as a rule remained in the comparatively still water within the vessel, often spinning their cocoons and successfully pupating. The young and half-grown larvæ seemed invariably to detach themselves and would be found within two hours gathered on the surface over which the water was flowing.

At one time the attention of fish culturists was drawn to *Simulium*, as the larvæ were stated to cause the death of young trout by entangling them in a silken web. This was disproved in the American Entomologist and Botanist, in 1870, by Mrs. Sarah J. McBride,¹ who clearly demonstrated that the "death web of young trout" was a myth, and that the threads were not strong enough, or interwoven, so that fish could be entangled in them.

¹ See Bibliography, p. 35.

THE FOOD OF THE LARVÆ.

The food of the larvæ is entirely microscopic. There are various accounts given on this subject by different authors, and they are somewhat divergent. Riley says that they feed on animalcules, but do not disregard microscopic matter of vegetable origin. He also states, that larvæ kept in a jar were seen to swallow the minute larval forms of small crustaceans belonging to the Copepoda and Isopoda, and that a number of square diatoms, joined together in chains, were found in the alimentary tract.

Miall says that he has found in the alimentary tract flinty valves of diatoms, desmids, and pieces of small crustaceans.

Kellogg, in his article on the food of *Simulium* and *Blepharocera*, states that he found thousands of tiny siliceous shells of diatoms in the intestines. They caused considerable difficulty in the making of microscopical sections for histological study. He also states that the larvæ feed on the stalked *Gomphonema* and occasionally on the genus *Nitzschia*. They are also stated to feed on *Vaucheria* and *Nothrix*.

The writer has found that the color of the larva varies according to the nature of the stream, and that the larvæ seem to thrive best in streams containing the largest proportion of such organisms as *Euglena viridis* and *Spirogyra*. Larvæ in running water were observed feeding in specially constructed glass tanks, and were seen to reject large *Paramoecia* and apparently anything except the smallest particles of the plankton. A striking fact seemed to be the effect of different foods upon the color of the larvæ. When the tank containing the food of the larvæ was filled only with water, decaying vegetable matter, and living grasses, the larvæ became emaciated and starved to death; but on the introduction of green algæ and *Spirogyra*, they regained their vitality and the alimentary tract changed from a light brownish yellow to a bright green. Dissections of the alimentary tract showed normally a quantity of green rod-like algæ, flinty shells of diatoms, and some minute star-shaped animalculæ. The larva of *Simulium pictipes*, which lives in the larger streams, has the alimentary canal filled with a quantity of sand; and the color is always brown corresponding to the brown growths on the rocks. The streams in South Carolina, which were contaminated by chemical refuse from the cotton mills, were absolutely free from larvæ, and this fact is of economic importance as it may be utilized further in the control of the larvæ. Pure animal sewage is not deleterious to the growth of the larvæ, provided the other environmental factors are favorable.

THE PUPAL STAGE.

METHODS OF PUPATION.

The histoblasts of the pupal and adult organs are formed in *Simulium* larvæ some considerable time before pupation takes place, and can be discerned when the larvæ are half grown, shortly after the second molt. The pupal respiratory organs, composed of long tubelike filaments (Pl. V, fig. 1), can be seen underneath the larval skin, on the sides of the anterior portion of the thorax, lying coiled up and visible as rounded darkened areas which become almost black as the pupal stage approaches. (Pl. III, fig. 7, A, A.) Shortly after the molt preceding pupation the chitinous hooks on the dorsal and ventral surfaces of the abdomen of the pupa become well developed underneath the larval skin.

Before commencing to pupate the larva spins over itself a pocket-shaped pupal case, formed of the strong silken threads supplied by the salivary glands. The shape and texture of the pupal cases vary according to the species. Of the five species discussed in this paper, four have pupal cases of the shape that may be described as the "wall-pocket" type, the texture finely spun, almost leathery in appearance, the cases being spun as a rule well separated from one another, and the distal end wide and rather open. (Pl. V, fig. 2.) *S. pictipes* is the exception, having the pupal case shaped after the fashion of a boot (Pl. V, fig. 5), the heel always pointing downstream, the pupal cases often overlapping one another in a coral-like formation, the texture coarsely spun, very tough, and the distal end narrow.

Shortly before the larva has finished making the pupal case the air from the tracheæ, entering the extension leading from the base of the main trunk from which the branch filaments arise, slowly creeps along the entire length of the filaments. The skin splits along the dorsum of the thorax and the filaments are at once projected into the water. The skin behind the head is then worked off toward the caudal end of the larva and the old tracheæ are withdrawn through the spiracular openings. The inner lining of the hind gut, together with the anal gills, which are formed of the same epithelial layer, is then cast out through the anal slit which is situated just above the X-shaped sclerites on the dorsal surface at the posterior end of the larva, and may be seen attached in the interior of the cast larval skin, which often remains for a while within the pupal case. The skeleton of the head of the larva is then pushed off downward to the front, the wall of the alimentary canal, about as far as the junction of the pharynx and the œsophagus, coming away with it. The pupa seems to lock itself in the pupal case by means of the

strong hooks on the dorsal and ventral surfaces of the abdomen. These hooks are turned anteriorly on the dorsal surface on segments 2, 3, and 4; posteriorly on the dorsal surface of segments 7, 8, and 9, and all hooks on the ventral surface are turned anteriorly. The whole operation of pupation and of spinning the pupal case takes from 4½ minutes to 1 hour.

GENERAL DESCRIPTION.

The pupæ of *Simulium* at first are generally golden yellow or light brown, the color and shape of the adult organs showing very clearly through the pupal skin as the time of emergence approaches. There are nine abdominal segments. On each side of the thorax are situated the respiratory organs, composed of long chitinous tubes, arising from a main stalk, tapering somewhat, and usually branching dichotomously toward the distal end. The number of filaments, always counting the branches of the distal ends, varies according to the species, from 4 to 60, and is an excellent systematic character, as it is very constant for each species. On the dorsal and ventral surfaces of the abdomen are situated rows of strong chitinous hooks. These seem to be of little use as distinguishing characters for the five species discussed in this paper, as they are approximately the same in number and have about the same position in each. The pupæ can be positively correlated with the adults by the dissection of mature male pupæ and study of the genitalia.

The pupæ of *S. bracteatum* and *S. jenningsi* have not been previously described, and the following descriptions are given:

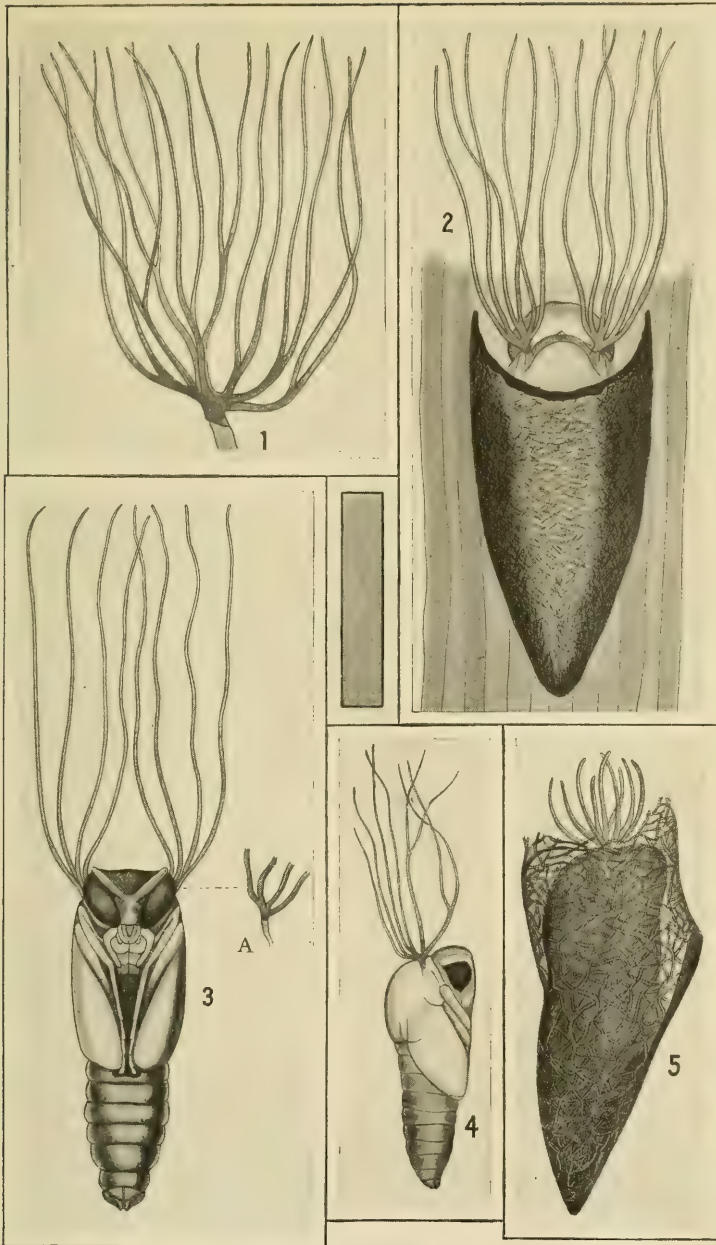
DESCRIPTION OF PUPA OF *SIMULIUM JENNINGSI*.

The pupa of *S. jenningsi* (Pl. V, fig. 4) is not more than 2.5 mm. in length, and is golden yellow when first formed.

The respiratory filaments, which are situated at each side of the thorax near the head, are each composed of a single main trunk, which divides at base into the following branches: Four single unbranched filaments and two long filaments, each of which divides again dichotomously, making eight branches in all, counting the distal ends of the branches.

On the dorsal surface of the abdomen there is a row of very small hooks on each side of the second segment, and on the third and fourth segments rows of four very large hooks on each side pointing cephalad. On the fifth segment there is a row of hooks pointing caudad, and on the ninth segment a row of minute hooks near the cephalic margin and a single large hook on each side at the middle of the segment. On the ventral surface of the abdomen there are two large hooks close together on the fifth segment, and two large hooks, rather far apart, on each of the sixth and seventh segments. The caudal end of the pupa is cleft for a short distance in the middle.

The pupæ studied were reared from larvæ and determined from adults reared from them and compared with the type.



PUPÆ OF SIMULIUM.

FIG. 1.—Respiratory filaments of pupa of *Simulium vittatum*. FIG. 2.—Pupa of *Simulium venustum*, in pupal case. FIG. 3.—Pupa of *Simulium bracteatum*: A, side view of filaments. FIG. 4.—Pupa of *Simulium jenningsi*. FIG. 5.—Pupa of *Simulium pictipes*, in pupal case. All greatly enlarged. (Original.)

DESCRIPTION OF PUPA OF *SIMULIUM BRACTEATUM*.

The pupa of *S. bracteatum* (Pl. IV, fig. 3) measures about 4 mm. in length and is of a golden yellow color when first formed.

The respiratory filaments are composed of a single main trunk on either side of the thorax, each of which divides in the following manner: Two long branches arise from the base of the main trunk, which again divides a short distance farther up, making four long branches on each side, counting the branches at the distal ends. The hooks on the abdomen are arranged as usual.

The pupæ were reared from larvæ and determined from adults reared from them and compared with the type.

DURATION OF PUPAL STAGE.

The duration of the pupal stage of *S. venustum*, according to Mrs. Sarah J. McBride, at Mumford, N. Y., is three weeks. The maximum period in the pupal stage of the same species observed by the writer was nine days at Havana, Ill., late in the fall, the average temperature during that period being 36° F.

The minimum period in the pupal stage of *S. venustum* was a little over 84 hours at Spartanburg, S. C., during the month of June, with a temperature from 70° to 90° F. The average length of the pupal period for the five species under consideration, during the summer, is from five to seven days.

The general effect of low temperature seems to be to retard, and of rising temperature up to 90° F. to hasten the emergence of the adult from the pupa. The effect that low air temperature has on the pupa in retarding development is much less in proportion than the effect that a rising temperature between 60° and 80° F. has in hastening emergence. Though their structure is normally adapted for aquatic life, yet when they are exposed to the air, as sometimes happens when the water falls, they will often emerge even after 24 hours spent out of water if the adult is sufficiently developed within the pupal skin. This was especially noticeable at Havana, Ill., in 1912, when the river began to fall.

The respiratory system of the pupa is a modification of the general tracheal system of the larva. The rectal gills having been cast off, their function appears to be assumed by the tubelike filaments arising on each side of the thorax. There are two long main trunks extending down each side of the abdomen. These give off branch tracheæ, connected by commissures, which lead to the abdominal spiracular chambers, from which arise the initial threads leading to the spiracles. The spiracles are cuticular invaginations and become closed, according to Taylor,¹ on the withdrawal of the old tracheæ at the time of the

¹ Taylor, T. H. On the tracheal system of *Simulium*. In Trans. Ent. Soc. London, f. 1902, p. 701-716 (p. 703), 8 fig., 1902.

shedding of the larval skin. From the mesothoracic spiracular chamber extends a broad tracheal trunk leading to the base of the main trunk of the respiratory filaments, which do not contain tracheæ, but are hollow. According to Taylor,¹ the air is not taken directly into the gill base from this hollow space, but is absorbed through the external chitinous fibrillæ and thence into the tracheal extension through a membrane.

EMERGENCE FROM THE PUPAL STAGE.

Four or five hours before emergence there is a very noticeable intermittent movement of the adult within the pupal skin, which is gradually distended with air toward the anal extremity, the abdominal tracheæ being probably withdrawn through the spiracular openings. Coincident with this the anal portion of the adult is withdrawn from the pupal skin and a threadlike membrane, seemingly the lining of the hind intestine, may often be seen extending from the anus of the adult to the pupal skin, to which it remains attached after emergence. As the pupal skin is locked by the strong chitinous hooks to the pupal case, the adult exerts a strong pressure toward the cephalic end and the pupal skin splits along the dorsal portion of the thorax and head, forming a T-shaped aperture. The adult at once rises to the surface of the water surrounded by a bubble of air which has been collected in the distended pupal skin, and running along the surface of the water at once takes flight. The curious way in which the adult rises to the surface surrounded by a bubble was commented on by the earliest writers on the group, and in situations where the pupæ are found in thousands, as in parts of Hungary, and along the Illinois and Mississippi Rivers in America, the water seems almost to boil as they emerge.

LIFE CYCLE AND NUMBER OF GENERATIONS.

The number of generations varies according to the species and the latitude. In the Southern States the species seem to breed continuously from about the middle of March until the approach of severe cold weather, generally about the end of November. The life cycle of one generation during the summer takes approximately four weeks; 7 days in the egg stage, 17 days as larvæ, and 4 days as pupæ. The time from the egg to the adult stage varies according to the rise and fall of the temperature. There are probably from five to six generations annually in South Carolina of the species here dealt with, except *S. pictipes*, which normally has three generations. In Illinois there are only three or four generations of *S. venustum* annually.

¹ Loc. cit.

INSECT ENEMIES AND PARASITES.

The larvæ of *Simulium* are often parasitized by nematode worms of the genus *Mermis*, specimens of which have been found by the writer measuring 12 mm. in length. These were found in larvæ of *S. venustum*, coiled around the intestines, and extended from near the caudal end to the thorax. The specimens that attained the greatest length were found singly, but as many as four have been found in individual larvæ. According to Strickland (1911),¹ the *Mermis* retard the development of the pupal and adult histoblasts, cause the death of the larvæ, and escape through punctures made in the epidermis. He also states that in the vicinity of Boston, Mass., *Mermis* was found parasitizing larvæ only during the spring, and that there is a seasonal variation of parasitism. The writer, while in South Carolina, found species of *Mermis* parasitizing larvæ from May until late in October, and these larvæ seemed to have developed the pupal histoblasts to a much greater extent than is estimated by Strickland. The larvæ are also heavily attacked by glugeid and gregarine species of *Myxosporidia*.

The writer has found the larvæ being attacked by species of *Hydropsyche* in Illinois and South Carolina. Dr. Howard (1888)¹ also mentions this fact in his article on a species of *Simulium* at Ithaca, N. Y., and gives a fuller account in the Annual Report of the U. S. Commissioner of Agriculture for 1886, page 510. Species of minnows attack the larvæ frequently, and Riley² mentions that the small fishes of the family Cyprinidæ also feed on them.

The pupæ, so far as is known, are not parasitized by *Mermis* or *Myxosporidia*. The adults have been found by the writer at Spartanburg, S. C., to be frequently parasitized by nematode worms of the genus *Mermis*, which were usually found singly. In one instance three of the worms were found in a female *S. venustum*. The same number were found in a female of *S. bracteatum*. They were situated in the abdomen, coiled around the Malpighian tubes and intestines, and in some cases extended into the thoracic region. The vitality of these specimens infested by the *Mermis* seemed to be seriously affected, though they lived for some time, 31 hours being the minimum and 72 the maximum period. All of these specimens thus parasitized were reared from pupæ, with the exception of one adult female of *S. bracteatum*, which was taken flying around a lamp at night. No adults taken biting on animals were ever found to contain *Mermis*.

¹ See Bibliography, p. 35.

² Riley, C. V. Report of the Entomologist. In Rept. U. S. Comr. Agr. f. 1886, p. 459-592 (p. 510), 11 pl., 1886.

Georgewitch¹ describes a trypanosome, *Crithidia simuliae*, which he found in the stomachs of adult females taken biting cattle, etc. The locality in which the animals were attacked was a district in Servia, and the species *S. reptans* (= *S. columbaschense*). He did not, however, find any similar organism in the blood of the animals attacked.

Riley² states that Lugger observed them being attacked by Asilidæ and Odonata.

Wise (1911)³ reports that in British Guiana the adult females of *Simulium* are attacked by a voracious enemy in the nature of a black and white wasp (probably *Monedula signata*), which follows the aboriginal Indian to obtain the "Pium" (*Simulium*). This wasp reduces the "Pium" to unconsciousness, deposits eggs, and leaves the body to be fed upon by the resulting larvæ.

SIMULIUM AS A POSSIBLE CARRIER OF DISEASE.

In 1874 J. P. Megnin⁴ strongly advanced a theory that two species of *Simulium* in the Department of the Rhone, France, are the transmitting agents of virulent charbon. He also mentions *Stomoxys* and *Haematobia* in this connection, but places most emphasis on *Simulium*, whose habits more closely conform to the outbreaks and distribution of the disease in that locality. He also states that, in his opinion, M. Tisserant, sent by the French Government to investigate the subject, proved that *Simulium* was the cause or the transmitting agent of the disease. In a later paper he reaffirms his statements and mentions that he has found a "Psoriasis guttata" prevalent in the ears of horses, and believes it is due to the bites of *Simulium*. The writer has found a similar condition to be very common in the ears of horses, undoubtedly due to the bites of *Simulium*, in Illinois, South Carolina, and the vicinity of Washington, D. C. As this condition may be of a purely secondary nature, and as apparently no experimental or careful analytical work has been done on the subject, all statements regarding the transmission of a disease of cattle by *Simulium* must be regarded as purely theoretical.

According to Riley and other authors, *S. pecuarum* Riley and *S. meridionale* Riley were supposed to carry cholera among chickens and hogs, but nothing definite was ascertained on this point.

¹ Georgewitch, Jivoïn. Sur un Trypanosome nouveau, *Crithidia simuliae*, n. sp. d'une Simulie (*Simulium columbacensis*) de la Serbie septentrionale. In *Compt. Rend. Soc. Biol.*, t. 67, no. 31, p. 480-482, 1 fig., Nov. 12, 1909.

² Op. cit., p. 510.

³ See Bibliography, p. 35.

⁴ Du rôle des mouches dans la propagation du charbon et autres affections virulentes. In *Jour. Med. Veter. Mil.*, t. 12, no. 8, p. 461-475, Paris, Jan., 1875.

In 1905 Dr. Louis Sambon advanced the theory that pellagra might be transmitted by a blood-sucking fly of the genus *Simulium*. An accurate knowledge of the biology of the genus is very necessary in order to prove or disprove such a theory. It must be proved that *Simulium* not only bites in very large numbers, in order that a sufficient percentage of specimens will become infected which will live and become capable of transmitting pellagra, but it must also be proved that they will bite man after they have become infected, since hereditary transmission is probably entirely out of the question. *Simulium* exists in many places in large numbers, and if it should be proved that it normally requires a meal of the blood of vertebrates before it can fully develop the ovaries, then the chances that it may become infective are greatly increased.

Evidence on these points may be obtained in the following three ways:

(1) By rearing adult females from the immature stages, and then allowing them to engorge, oviposit, and reengorge. This method was tried a number of times, but with no success, for the fly will not readily engorge while in captivity, as was noted in the discussion of the feeding habits of the adult.

(2) By the capture of adults actually feeding on mammals, and by inducing them to oviposit and then to reengorge. This method also was unsuccessful for the same reasons.

(3) By dissections. If it could be proved that when a *Simulium*, which has once engorged on blood and oviposited, is still in a condition favorable to a second oviposition—that is, if rudimentary eggs are present in the ovaries awaiting only a second blood meal for their successful development—then there would be a more definite basis for a theory of disease transmission as opposed to the theory of merely a close coincidence in the distribution of pellagra and *Simulium*. This is the method adopted by the writer and is the one discussed in the following pages. The experiments were concluded in Spartanburg County, S. C., a country very favorable for the production of *Simulium*, being hilly and with a network of small streams, rapid and especially suitable for the development of the immature stages. The experiments on the actual biting and feeding habits were carried on more or less continuously from June 13 to September 16. The material for these experiments consisted of specimens of *S. venustum*; a good series of reared specimens (about 30); a number of females found engaged in oviposition; about 300 females all of which were taken in the act of engorging on mammals. Of the last named only about 90 were successfully dissected, as the engorged adults after death became internally disintegrated and hardened after an hour or so, despite every precaution. Many also died between midnight and 7 a. m., or while they were being transported from the place of

capture to the laboratory. The adults, with the exception of 10 specimens killed at the time of capture, were kept alive as long as possible and dissected as soon as death was imminent. Some, in order that data might be obtained on their condition at the time of engorgement, were killed when captured and dissected within an hour.

RECORDS OF DISSECTIONS.

DEVELOPMENT OF THE OVARIES OF REARED NONFED ADULTS.

In order to have a check on the experiments with engorged adults, 32 females reared from isolated pupæ were kept alive as long as possible, without food, in bottles containing damp cloths. There were a number of males, reared from this same lot of pupæ, at liberty within the breeding cage together with these females, and copulation probably took place, but no definite statement can be made with regard to this point. Four females were killed and dissected within 6 hours after emergence. The remainder lived from a minimum period of 14½ hours to a maximum of 119 hours. All these specimens on dissection contained rather transparent ovaries of great potential development and full of round eggs (stage 1) (Pl. I, fig. 1, p. 4). In no instance did any one of these specimens develop the eggs within the ovaries as far as even the second stage. The maximum longevity of any nonfed reared specimen exceeded the maximum longevity of any specimen taken after engorgement by 52 hours. It would seem, therefore, that of these 32 reared specimens, there would have been 1 or 2 which would have developed the eggs within the ovaries, if it had been in the natural course of events for them to do so.

CONDITION OF THE OVARIES OF FEMALES FOUND OVIPOSITING.

Eleven females were taken actually engaged in oviposition on grass blades in streams. When these specimens were dissected, there was found in each stomach a certain amount of substance closely resembling the digested blood found in engorged specimens which had lived after engorgement for 40 hours or more previous to their dissection. A chemical test for hæmatin was applied to the substance found in the stomachs of the females found ovipositing, in order to prove beyond doubt whether it contained animal blood or not, but, owing to the small quantity and the changes consequent to the process of digestion, it was impossible definitely to determine its character.

Three specimens were taken from grass blades in a stream on which they had just alighted and had not begun to oviposit. These specimens were at once dissected, and their ovaries were found to contain from 250 to 300 fully developed eggs. Four specimens were taken from egg masses deposited in the same situation, which had evidently

just finished ovipositing. Four others which subsequently laid from 89 to 349 eggs while in captivity were also captured. The adults lived after oviposition from 15 minutes to $67\frac{1}{2}$ hours, and were dissected immediately after death. Their ovaries were found to contain in each case a large quantity of eggs of the round type corresponding to stage 1 (Pl. I, fig. 1) with the exception of the specimen which lived only 15 minutes after oviposition and in which the eggs within the ovaries were only visible under a high magnification. The ovary of one specimen contained in addition, near the oviduct, a large fully developed egg which had not been deposited. This last-mentioned condition (stage 5, Pl. 1, fig. 5) was also found in adults taken engorging upon mammals and killed at the time of capture.

CONDITION OF THE OVARIES OF ADULTS TAKEN FEEDING ON MAMMALS.

In order to demonstrate the relation between the amount of engorgement and its apparent effect upon the development of the eggs within the ovaries, the condition of the ovaries is discussed collectively with regard to the previous amount of engorgement by adults, irrespective of the dates on which the adults were captured.

The following symbols are used in description to separate the varying degree: (+) Slight and partial engorgement, or about one-fourth the utmost capacity; (++) fair engorgement, or one-half the utmost capacity; (+++) well engorged, or three-fourths the utmost capacity; (++++) complete engorgement, or distension of the abdomen to its utmost capacity.

CONDITION OF THE OVARIES OF ADULTS KILLED AT TIME OF CAPTURE.

Ten adults were taken from time to time engorging on the blood of mules. They were killed at once to obtain data on the condition of the ovaries at the time of engorgement. Two specimens were slightly engorged (+); in one the ovaries showed a condition corresponding to stage 5, each ovary containing about 12 fully developed eggs, the remainder of the ovary being filled with eggs of the round type; in the other the ovaries contained only eggs of the round type in large quantity (stage 1). One specimen was half engorged (++) ; its ovaries were in a condition typical of stage 5, being filled with small round eggs and containing in addition 8 large fully developed eggs in a free condition, which seem positively to have been developed at a different period from the rest of the ovaries. One specimen was fairly engorged (+++) ; the ovaries contained only eggs of the first stage in large numbers (stage 1). Six specimens were taken fully engorged (++++) ; all of the ovaries were in a condition typical of stage 1, the eggs being of the small round type, translucent, and in large numbers.

In conclusion, there were only two stages found in the ovaries of adults killed at the time of capture, either small, round, undeveloped eggs in large quantity (stage 1), or round undeveloped eggs with the addition of a very few large, fully developed eggs (stage 5). This latter stage is presumably the result of a previous engorgement and oviposition.

CONDITION OF THE OVARIES OF NONENGORGED ADULTS TAKEN ON ANIMALS.

Six specimens, which had evidently just alighted and had not fed on that particular animal, were taken at various times from mules' ears. They lived from 2 to 47 hours after capture, and the condition of the ovaries in all these specimens was typical of stage 1. There was no development of the eggs within the ovaries, and the condition seemed to be the same as in adults reared from pupæ and dissected shortly after emergence.

CONDITION OF THE OVARIES OF PARTLY ENGORGED ADULTS.

Twelve specimens were taken which had partly engorged (+). The eggs within the ovaries of five of these specimens were not developed at all, and showed a condition corresponding to stage 1. These lived from 16 to 30 hours after capture. Three specimens showed the ovaries in a condition typical of stage 5, with from 1 to 4 fully developed eggs near the oviduct, and with the remainder of the ovaries filled with the small round type. These individuals lived from 12 to 21 hours after capture. The ovaries of two specimens which lived for 52 and 53 hours, respectively, contained a large number of eggs between stages 2 (Pl. I, fig. 2) and 3 (Pl. I, fig. 3), almost oval in shape, about 200 in all. Two adults were slightly more engorged than the rest, though not quite half engorged. They contained ovaries with eggs fully developed, of the same size and shape as eggs freshly deposited, but in very small numbers as compared with those found in adults dissected before oviposition. There were about 30 eggs in the ovaries of one and 50 in the other, which lived 45 and 47 hours, respectively. These adults had possibly engorged once, oviposited, and then developed the remaining eggs in the ovaries.

In the condition of the ovaries of partly engorged adults these two points are worthy of notice: (1) No development of the ovaries took place unless the longevity of a specimen exceeded 40 hours; (2) stage 5 recurred in three cases.

CONDITION OF THE OVARIES OF HALF-ENGORGED ADULTS.

Five half-engorged (++) adults were taken. The ovaries of two specimens contained eggs of the round type typical of stage 1. They lived for 7 and 21 hours, respectively. One adult contained ovaries filled with eggs of the typical oval shape (stage 3) in large

numbers and dense white in color. This adult lived for 53 hours after engorgement. Two adults contained ovaries with fully developed eggs in small numbers. In one adult there were 25 eggs in each ovary and in the other 18. Both these adults lived for only 4 hours and 35 minutes after capture. This is probably a case of second feeding, because adults which lived for so short a period after engorgement could not have developed fully formed eggs in that time. The explanation of this condition is that they had probably deposited only part of the full number of eggs at a previous oviposition.

CONDITION OF THE OVARIES OF WELL-ENGORGED ADULTS.

Twelve well-engorged (+++) adults were taken on various dates, these specimens lived after capture from 7 to 47 hours. Only one specimen contained ovaries corresponding to stage 1. This specimen lived only seven hours and evidently had not had sufficient time in which to develop the ovaries. One specimen, which lived 17 hours, contained ovaries filled with eggs of stage 2, thus showing that the amount of development corresponds to the amount of engorgement and the requisite length of time after feeding. Six specimens, which lived from 17½ hours to 24 hours 45 minutes, contained ovaries filled with eggs of the oval type typical of stage 3, again showing a constant amount of development in proportion to the previous engorgement and subsequent longevity. One specimen, which lived for 43 hours, contained eggs of the oval type in a very small number, about 20 in each ovary, with the remainder of the ovary apparently filled with the eggs of the round type (stage 1). One adult contained ovaries with fully developed eggs, but only 27 in each ovary. This specimen lived for 30 hours. Two adults contained ovaries filled with fully developed eggs, over 100 in each ovary. These lived for 47 hours and evidently had the required factors, presumably a sufficient blood meal and sufficient time in which to digest, in order to develop the eggs within the ovaries.

The foregoing data seem to show again that the development of the eggs within the ovaries is increased by the amount of food plus the length of the period of digestion.

CONDITION OF THE OVARIES OF FULLY ENGORGED ADULTS.

Thirty-one fully engorged (++++) adults were taken from time to time and successfully dissected. They lived from 30 minutes to 67½ hours. Six specimens contained ovaries corresponding to stage 1. These lived from 30 minutes to 4 hours 35 minutes. Two adults, which lived 17 and 24 hours, respectively, contained ovaries with the eggs between stages 2 and 3. Six specimens contained ovaries with eggs typical of stage 3 in large numbers. These lived from 18 to

28½ hours. One specimen which lived 23½ hours contained ovaries with only a small number of eggs, about 25 in each ovary. One adult which lived for 44 hours contained ovaries between the third and fourth stages, and showed the transition from stage 3 to stage 4 very clearly. Twelve adults contained ovaries filled with fully developed eggs (stage 4, Pl. I, fig. 4), ranging in number from 200 to 300. These adults lived from 30 to 67½ hours. Two adults contained ovaries with eggs of stage 4, but in small numbers, about 50 in each ovary. They lived 48 and 56 hours, respectively, and possibly had developed the remainder of the eggs left within the ovary after a previous oviposition. One adult contained ovaries with eight fully developed eggs, and the remainder of the ovary filled with eggs corresponding to stage 3. This adult lived 34 hours and had presumably oviposited once, as is indicated by the presence of the eight fully developed eggs, and then developed the remainder of the ovaries to stage 3.

A comparative study of the ovaries of well-engorged (+++) specimens shows that no adult which died before reaching a period of longevity of 30 hours after engorgement developed the eggs within the ovaries to full degree. On the other hand, with one exception, all adults which lived for 30 hours after engorgement developed the eggs within the ovaries to the fullest extent. The fully developed eggs within the ovaries were of the same shape as eggs freshly laid, and only a fraction smaller.

THE APPARENT EFFECT OF A BLOOD MEAL UPON THE DEVELOPMENT OF THE OVARIES.

In the studies which have been made of the ovaries of females of *Simulium venustum* under various conditions the following points are worthy of emphasis: (a) In all adults taken while ovipositing, apparently digested blood was found in the stomach. (b) No eggs within the ovaries developed to the fullest degree without engorgement and the requisite time in which to digest the blood meal. (c) The condition designated as stage 5 occurred both in adults which had just oviposited and also in adults which were taken on animals and killed at the time of capture. This condition (stage 5) seems to furnish strong evidence that adults feed again after ovipositing, as the majority of engorged adults showed the entire contents of the ovaries developed. In addition the exact cause of the similar condition found in adults which had just oviposited is known; namely, that a few fully developed eggs were left in the ovaries after oviposition and the remainder of the eggs were in a rudimentary condition apparently awaiting the necessary factors for development. (d) The males have reduced mouth parts and are not found engorging on blood, indicating the acquisition of this habit by the females for a special purpose, as is the case with other blood-sucking Diptera.

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THE MILLING OF RICE AND ITS MECHANICAL AND CHEMICAL EFFECT UPON THE GRAIN.

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INTRODUCTION.

GEOGRAPHICAL DISTRIBUTION AND VALUE OF THE RICE CROP.

From early colonial days until the Civil War, rice was an important crop in the coastal plains of South Carolina and the adjacent States. During the past quarter of a century, however, the production of rice in Louisiana, eastern Texas, and Arkansas has risen to a preeminent position. Of the 1913 rice crop of the United States, valued on the farm at \$22,090,000, approximately 45 per cent was grown in Louisiana, 38 per cent in Texas, and 15 per cent in Arkansas. The relative importance of the rice-producing areas of the United States is shown in figure 1. With the opening of the great southern prairies of Louisiana and Texas for rice culture and its more recent development in Arkansas, the production of rice in the United States has increased enormously. Not less striking, however, have been the improvements in the methods of planting, harvesting, thrashing, and milling.

Much has been written about the new agricultural schemes for producing the rice crop, but very little literature is available on the milling processes now in use. It is the object of this paper to describe

briefly these processes and the machinery employed, and to consider each operation in the light of its effect on the chemical and mechanical qualities of the finished products. It is hoped that in so doing it may be possible to correct some of the popular misunderstandings of the various grades and finishes of rice now found on the market.

STRUCTURE OF THE RICE GRAIN.

A brief description of the physical and microscopic structure of the rice grain is of such value in understanding the milling processes that it is presented here. Prior to 1914 about half of the rice grown in the United States was of the Honduras type and nearly all the remain-



FIG. 1.—Outline map of the United States, showing the relative importance of various rice-producing areas in 1914; each dot represents 50,000 bushels.

der was of the Japan type, each deriving its name from the country from which it was originally imported.¹ The grain of the Honduras type of rice is long and slender, that of the Japan type distinctly smaller and more nearly round, but from the viewpoint of the structure of the grain the two are virtually the same.

The rice grain as it leaves the farm thrasher and enters the mill is covered with a hard, siliceous hull, or palet, which is loosely attached to the edible grain within. The germ, or embryo, is distinctly visible near the base of the hulled grain. Directly beneath the hull, but separate from it and firmly attached to the starchy body of the grain itself, is a light-brown bran coat. A careful study of this coat with the microscope reveals seven types of cells arranged in layers and enveloping the starchy interior of the grain. Figure

¹ In 1914 the rice known commercially as "Blue Rose" was first widely grown throughout the rice belt. In shape and size the grains of Blue Rose rice are intermediate between those of the Honduras and the Japan types.

2 represents a cross section of a rice grain, and shows, in addition to the hull, the disposition of the seven layers. On the outside of the hulled grain lie, in order, the epicarp, mesocarp, cross cells, and tube cells. These four are frequently grouped together and called the pericarp. Beneath this are the spermoderm, perisperm, and aleurone layers.

During the process of milling, there are removed, in addition to the hull, most of the outer six coats and a portion of the seventh, leaving only the starchy part of the endosperm surrounded by a portion of the aleurone layer. Since the aleurone cells are rich in

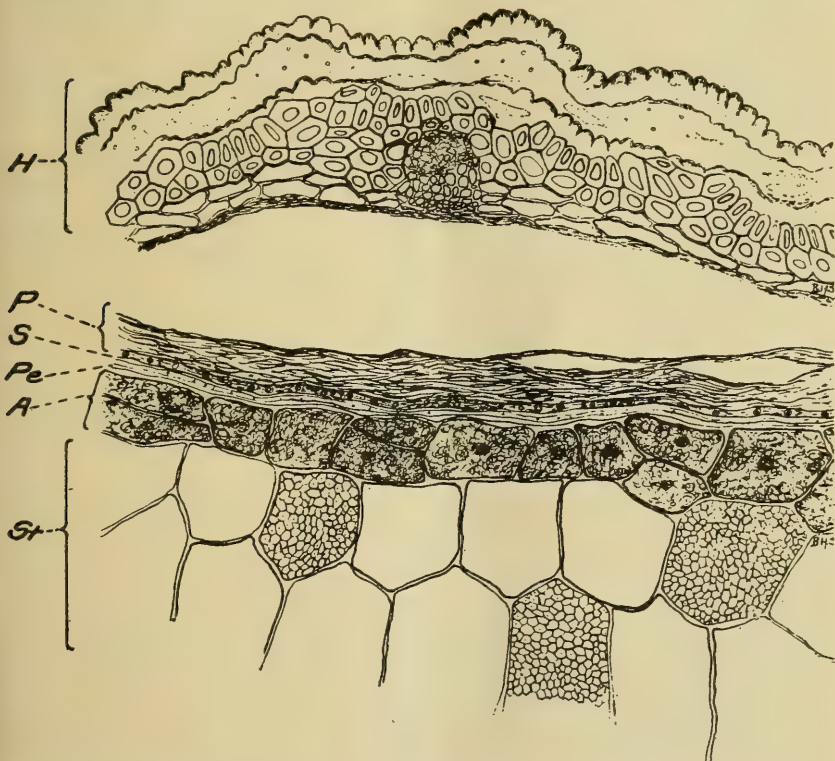


FIG. 2.—Cross section of the hull and outer portion of a rice grain, greatly magnified. *H*, Hull; *P*, pericarp (including the epicarp, mesocarp, cross cells, and tube cells); *S*, spermoderm; *Pe*, perisperm; *A*, aleurone layer; *St*, starch cells.

protein and this constituent is also present in the protoplasm distributed through the endosperm, it is not surprising that only about 10 per cent of the protein of the hulled rice is removed by milling. The oil, however, is largely contained in the germ, and about 85 per cent of the entire oil content of the hulled rice goes into the by-products. Since the mineral salts of the hulled grain lie mostly in the exterior layers, the proportion of salts is reduced nearly 70 per cent by milling. Interesting, but of less importance, is the reduction of 70 per cent in the crude-fiber content by the removal of the

cellulose structure of epicarp and perisperm and a 30 per cent decrease in the quantity of pentosans.

MILLING METHODS.

EVOLUTION OF RICE MILLING.

The rice hull is so stiff and hard as to be quite inedible, and its removal from the grain is in reality the fundamental process of rice milling. To accomplish this, various devices have been used in the United States. The pounding of the grain in a wooden mortar with a pestle by hand was succeeded by the employment of mechanical devices for raising the pestle and by the use of larger mortars and pestles covered with metal on their wearing surfaces. In some localities a further refinement of the process consisted in substituting revolving stones as a hulling agent before the rice was pounded.

In Louisiana the same object was later accomplished by a machine called the "plantation huller," in which the rough rice was hulled and scoured by friction between corrugated iron surfaces. Modern mills employ large revolving stones for removing the hulls and a series of scouring machines for polishing the grain.

PRIMITIVE METHODS.

FARM MORTAR-AND-PESTLE MILLING.

In early times, when the production was small and consumption was confined largely to the producing area, simple and cheap methods of milling were adequate. The farm mortar was made by burning or scraping a conical cavity in a block of hard wood, and the pestle was prepared from a cylindrical stick of similar wood by shaping and pointing each end and cutting down the center to a size suitable for a handle. Such a pestle was about 3 feet long and weighed from 10 to 15 pounds. Figure 3 shows the type of wooden mortar and pestle formerly used in milling rice for home consumption. The rough rice was pounded until practically all the grains had been hulled and the broken hulls, acting as an abrasive, had scoured off a considerable portion of the bran coat. The loose hulls and bran were blown away by the wind when the pounded mass was poured from an elevated pan to a receiver below. Before cooking such rice it was necessary to remove by hand picking the remaining paddy or unhulled grains, which were always present. Since the capacity of a mortar was generally less than a bushel and the operations were all done by hand, this method was inadequate for the milling of rice except on a small scale.

MORTAR-AND-PESTLE MILLS.

As the demand for rice increased, it was found economical to employ larger mortars and mechanical means for pounding and winnow-

ing the grain. The mortars, enlarged to a capacity of 4 to 6 bushels each, were lined with iron, and the pestles, covered with the same metal, weighed 350 to 400 pounds each. All machinery in these mills was operated by power secured from small wood-burning steam engines. The pestles were raised and dropped into the mortars by means of a huge horizontal revolving drum, fitted with spokes which, as the drum revolved, passed into and under slots in the pestles, raising them up, passing out, and dropping them suddenly with a heavy thud into the mass of rice in the mortars. Machine-driven screens and fans were adopted, and the capacity of a mill employing six or eight mortars was over 700 bushels of rough rice per day. Mills of this type, which were located at various points along the South Atlantic coast, were the first to attempt a separation of the clean rice into grades according to size. This was done by the use of flat metal screens.

Very largely increased production in southwestern Louisiana and a demand for a more highly polished product resulted in further mechanical developments in the mills of that region. The rice was first screened to remove foreign matter, such as straw, weed seeds, and mud lumps. It then passed to a

pair of hulling stones, a new machine introduced to perform a part of the work formerly done by the mortar and pestle. The rice fell through an opening in the upper stone, and the revolution of this stone, or "runner," over the "bed stone," which was stationary, caused the grains to incline in a semiupright position between the two stones. The "runner," which revolved over the "bed stones" at a distance above it equal to about two-thirds the length of the rice grain, cracked or split the hull,



FIG. 3.—Wooden mortar and pestle used in milling rice by hand.

allowed the grain to drop out, and by its revolutions forced grain and hulls along together out of the machine. The runner stone was capable of being raised or lowered to suit the quality and size of the grain in various lots.

From the stones the material passed to a newly introduced combination "screen blower," which fanned out the hulls and partly separated the unhulled, or paddy, grains from the hulled rice. The paddy rice was returned to the stones and the hulled rice conveyed to storage bins above the mortars. In these mills the mortars were used only as scouring machines and removed most of the bran coat, together with the germ, or eye, of the grain. When the rice had been sufficiently pounded, it was transferred to the flour screen and thence to the fine-chaff fan for the separation of the by-products. The rice became heated through friction in the mortars, and it was therefore sometimes placed in cooling bins, where it was stored for eight or nine hours before further milling. The final polishing was accomplished by the friction of the grain in the polisher or brush. This machine consisted essentially of a vertically cylindrical framework which was covered with overlapping pieces of soft moose hide or sheepskin and revolved at a high rate of speed within a cylinder of wire screen. The rice was scoured between the leather and the wire screen and given a highly polished surface. Grading was done on flat metal screens, and the clean products were barreled for the market.

PLANTATION HULLERS.

Several small huller mills are still operating in various parts of Louisiana, cleaning rice for local use. Briefly the process is as follows: Power is secured from a small engine which drives belts for the operation of the mill machinery. The rough rice is first screened free from straw, chaff, and dirt and passed directly into the hopper of the huller. This huller resembles externally a large sausage machine and is composed of a horizontal, tapering, grooved cylinder within which revolves a ribbed shaft. The rice is subjected to a vigorous rubbing of the kernels against each other and to a scraping between the rough iron walls of the tapering cylinder and the ribbed surface of the rapidly revolving core. The grain is next screened and fanned free from hulls and passed a second time through the huller, after which it is again fanned and is ready for consumption. Such milled rice contains a large percentage of broken kernels which are covered with a film of powdery bran.

On account of the small motive power and little machinery used, the daily capacity of such a mill seldom exceeds 40 barrels of rough rice of 162 pounds each. The grower generally has his choice of

paying about 50 cents per barrel cash for the milling, in which case he retains the mixed hulls and bran, or of giving 30 cents together with the by-products. The yield of milled rice from a plantation huller approximates 80 pounds per barrel of rough rice of the Honduras type.

MODERN MILLING.

The large profit formerly derived from the modern rice mill, as well as the rapid extension of rice farming in western Louisiana and Texas during the past 20 years, led to an overconstruction of mills. In 1911 competition, which had become so vigorous as nearly to eliminate profits, resulted in the consolidation of about 30 Louisiana mills and the formation of the Louisiana State Rice Milling Company. To secure greater business economy and milling efficiency 12 mills were closed and many of the remaining 18 enlarged. In addition to the 30 mills of the Louisiana State Rice Milling Company, there are in Louisiana 11 independent mills, all operating in 1913, of which 8 are in New Orleans. Twenty mills are located in Texas, and all but two were operating in 1913. In Arkansas six mills were running during 1913 and one was closed. Tennessee has one operating mill at Memphis. On the Atlantic coast there are five mills, all of the mortar-and-pestle type, located in North Carolina, South Carolina, and Georgia, but only one of these is at present operating, and that on a very small scale.

MILLING MACHINERY.

The milling of wheat and of rice are fundamentally opposite. In milling wheat the chief product, flour, must be ground very fine; in milling rice the grains must be kept as nearly whole as possible. According to the present commercial conception, an efficient rice mill is one which properly cleans, scours, and polishes the rice grains with a minimum amount of breakage. This fact must be kept in mind in the study of each machine.

Screens and fans.—The rough rice from the thrashers, stored in bags in the warehouse or in bulk in the elevator bin of the rice mill, generally is thoroughly screened and fanned in a combination screen blower before being conducted into the hopper of the hulling stones. Chaff, weed seeds, mud lumps, and other foreign substances are thus removed, which, if present, would damage the machinery or introduce impurities into the finished products.

Hulling stones.—The first real milling operation consists of removing the hulls from the grain between the hulling stones. These latter are a perfected form of those employed in the old mortar-and-pestle mills already described, and differ little from the stones which are widely used for grinding corn. In a modern rice mill of a daily

capacity of 600 barrels of 162 pounds each, two sets of stones are generally employed. Since the revolving motion of the stones tends to keep the grains on end and all the grains in a lot of rice are not uniform in length, it is found most economical to adjust the stones at a sufficient distance apart so that the best and longest grains are not broken and at the same time a maximum percentage of rough rice is hulled. If the stones are set too close together, it is also found that the germs are removed from some of the grains instead of remaining to be scoured off with the bran. The average results of the mechanical analyses of several samples of rice of the Honduras type collected directly from the stones are as follows: Hulled rice, 65.5 per cent; rough rice, 15.3 per cent; and hulls, 19.2 per cent.

Fans.—From the stones the mixture of hulled rice, rough rice, and hulls is elevated to the upper mill floor to be fanned. The fanning device is very similar in this case to the one used in removing the dust and weed seeds from the original rough rice. The same forced air that separates the hulls from the rice usually takes them to the fuel house near the boiler room, where they are eventually used as

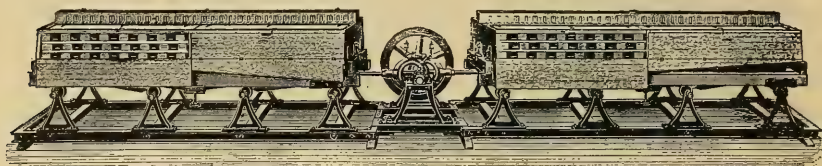


FIG. 4.—Typical paddy machines used in modern rice mills to separate the unhulled rice (paddy grains) from the hulled rice in the process of milling.

fuel for the mill, or, if they are not to be burned, to a grinding machine, where they are prepared for the market. Practically all rice mills make use of the hulls as a source of power for heating the boilers. Analyses of many samples of the Honduras type of rice taken from the fans show how efficiently the loose hulls are removed in this machine. The average results are as follows: Hulled rice, 81.9 per cent; rough rice, 17.2 per cent; and hulls, 0.9 per cent.

Paddy machine.—The paddy machine is a device designed to separate the rough from the clean rice in the mixture, which has been fanned practically free from hulls. Essentially it consists of a large inclined mechanically operated shaker, the surface of which is interrupted at regular intervals with small vertical metallic plates which divide the rice and aid gravity in making the separation. As the shaking proceeds the rough rice grains, being lighter, gradually move upward from the center feed and pass over the high side of the machine into a trough, while the heavier, hulled grains are collected under the lower side. The separation may be varied by changing the speed of shaking, the angle of incline of the platform, or the

rapidity of the feed. Four to six paddy machines are generally employed in a mill of 600 barrels daily capacity. The structure and arrangement of two paddy machines are shown in figure 4.

Table I shows the efficiency of the paddy machine in separating the unhulled from the hulled rice. In studying this table, it must be remembered that about 80 per cent of the rice passes out at the lower or clean-rice side of the machine.

TABLE I.—Average results of analyses of four samples of the Honduras type of rice secured from the feed boxes of paddy machines and of corresponding samples from the troughs at the clean-rice and rough-rice sides.

Product.	Rice (per cent) from—		
	Feed box.	Clean side.	Rough side.
Clean rice.....	81.85	98.98	16.56
Rough rice.....	17.25	1.02	77.68
Hulls.....	.90		5.76

The rice from the rough side of the paddy machines is returned to a pair of small stones which are set close together, where the short kernels are hulled and then combined with the rice from the first stones. The rice from the clean side is now practically free from hulls, but the grains retain the thin brown bran layer as well as the eye, or germ, intact.

Hullers.—The name “huller,” given to the next machine in the milling process, is very misleading, because in reality this machine is used for removing the bran layer from the grain which has been hulled by the stones and freed from rough rice by the paddy machine. The word “huller” is universally understood in this connection in the rice industry, and hereafter when the word appears in this bulletin it will designate the machine which receives the rice from the paddy machine and scours off the outer bran layers. The name was probably inherited from the similar machine, the plantation huller already described, which removed hulls as well as bran. The modern huller is somewhat smaller but otherwise very similar to that already described, and six or seven machines are necessary in a 600-barrel mill. The grain from the clean-rice side of the paddy machine is conducted to the feed hopper of the huller and thence passes into the cavity of the machine. A part of the bran layer on the outside of the grain and most of the germ are removed, largely by scouring between the rough inside iron walls of the tapering cylinder and the grooved surface of the rapidly revolving core. Figure 5 shows the type of huller used in modern rice mills. In this machine the milling quality of the rice is put to a severe test and the grain much whitened

by the elimination of the brown exterior bran coats. In some mills the rice is passed through a second set of hullers.

Bran reel.—The bran reel receives the product from the hullers and separates the rice from the powdery bran. This reel is composed of a large octagonal framework covered with fine wire screen, the square meshes of which are 14 per linear inch. The reel is set on a slight incline and its slow revolving motion takes the rice, which enters at the higher end, through its length of 9 feet in about 5

minutes. As the reel revolves, the rice constantly falls from side to side and forces the bran through the wire covering.

Pearling cone.—The pearling cone, which has recently been introduced in many mills to supplement the work of the hullers, is essentially the same machine that is used in the pearling of barley. The principal working part of the machine is a frustrum of a cone covered with a composition stone; this is surrounded by a sieve mantle composed of close-meshed heavy iron wire. The rice is fed from above between the stone and the sieve and is thoroughly rubbed before

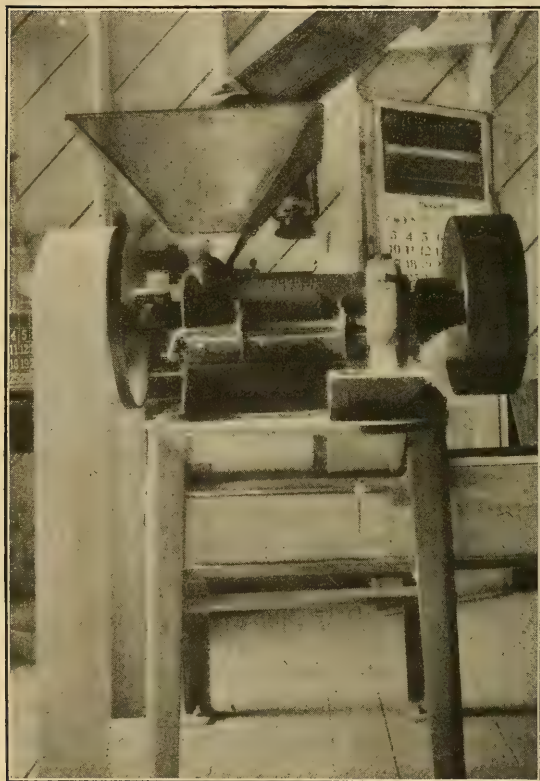


FIG. 5.—A typical rice huller, showing its exterior construction, belting, hopper, feed, milled rice, etc.

passing out at the bottom. The severity of the scouring is regulated by raising or lowering the stone, thus decreasing or increasing its distance from the wire screen. The best milling practice now approves the use of the pearling cone, because with its use the grain may be more gradually scoured than where the hullers alone are used and the breakage can also be kept lower. The loosely adhering bran resulting from the action of the pearling cone is removed from the rice in a bran reel. This bran is generally combined with

that removed by the hullers, but is occasionally mixed with the polish from the brush or even bagged and sold locally as rice meal.

Brush and brewer's reel.—The brush is the last scouring machine in the milling process. On account of the rapid feed necessary in securing the best results from the brush, the rice from the bran reel following the pearling cone is stored in large bins situated above the brush. This latter machine has already been described as the polisher of the mortar-and-pestle mill. In the modern mill it has been found advantageous to substitute pigskin for moose hide or sheepskin and to increase the speed of the machine. The very thin layer of bran which is rubbed off is forced through the surrounding screen as a light-brown powder, called rice polish. The rice kernel at this point is reduced approximately 10 per cent of its weight after the removal of the hull. As a rule, when a coating of glucose and talc is to be applied later in the process, the rice is not subjected to such a severe scouring in the brush as when it is to be sold as uncoated rice. From the brush the rice, containing all sizes from the most nearly perfect whole grains to the smallest particles, is passed into the brewer's reel for the first step in grading. This reel differs from that which removes the bran only in that the wire screen covering has 10 meshes instead of 14 to the inch in each direction. The brewer's rice which passes through the screen of this reel is never coated with glucose and talc, since its value is small and not increased by such a process involving extra expense.

Trumbles.—When the rice is to be coated with glucose and talc, as is generally done, it is transferred directly from the brewer's reel to the trumble for this purpose. The trumble is a cylinder about 9 feet long and 4 feet in diameter set on an incline of about 15° from the horizontal and revolved by a gearing on the outside. It is often provided with a steam pipe through its axis for raising the temperature of the rice, to effect a higher luster in cold weather. The rice, together with the coating materials, is introduced at the higher end of the trumble, and the shiny appearance is produced on the grain as it moves slowly round and round and ultimately pours out at the lower end. To the inside surfaces of the trumble are fixed several small strips of wood, which carry the rice up the side and let it fall again as the cylinder revolves, thereby increasing the friction on the rice grains. Glucose of a good quality, which is generally heated and mixed with a small proportion of water, is fed from a tank in a constant small stream upon the rice as it enters the trumble. Talc is introduced at the same place by means of a screw feed connected with a supply box. The quantity of each coating material added is regulated by the miller to suit the quality of the particular lot of rice being milled. No other coating materials than those mentioned have

been observed in use in the mills of the United States. In some cases a second trumble without glucose and talc feeds supplements the work of the first, and it is generally conceded that the extra friction gives to the rice a brighter and more desirable luster.

Table II shows the percentage of rice-coating material used in a large number of mills in Louisiana, Texas, and Arkansas. The figures given were calculated by ascertaining the daily output of the mills and the corresponding gallons or pounds of coating materials actually being applied. The considerable variation in the quantities of the coating material used, as shown in the maximum and minimum columns of the table, is due to the difference in the quality of the various lots of rice and to the interpretation of trade demand by the mill management. The averages show that the Honduras and Japan types of rices receive about the same quantities of coating materials, which approximate two parts of glucose and one part of talc per thousand parts of rice.

TABLE II.—*Glucose and talc added to milled rice.*

Type of rice.	Number of samples.	Glucose (per cent).			Talc (per cent).		
		Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.
Honduras.....	29	0.20	0.46	0.06	0.07	0.30	0.02
Japan.....	8	.19	.26	.09	.09	.20	.05

Grading machines.—From this stage to the ultimate bagging the problems met with pertain to the grading of the clean rice. However, if the rice is damaged or very inferior because of the presence of red rice, it is often bagged ungraded and sold as “line” rice. The shaker frame, which was the earliest device used for grading rice, is simply a framework, mechanically operated, which supports a set of inclined flat metal screens. These screens are removable at will and are numbered according to the sizes of the round perforations in them. The unit of measure is a sixty-fourth of an inch; hence, a No. 8 screen has holes eight sixty-fourths of an inch in diameter. Shaker frames are still used in practically all mills, to aid in the grading work. In most cases a considerable proportion of the “fancy head” grade is removed on the screens before the rice goes to the cockle cylinder.

If the quality of the rice being milled is exceptionally good an extra fancy head grade is made, which consists of the largest and most nearly perfect grains of the lot, with only a small percentage of broken particles. This commercial grade, if of the Honduras type, consists of that rice which does not pass through a No. 8½ screen on the shaker frame, and, if Japan, a No. 7½ screen. In passing the rice over the

screens of the shaker frame the small quantity of finely broken rice which failed of separation in the brewer's reel or resulted from a slight breakage within the trumbles is removed through a No. 5½ screen and combined with the other brewer's rice.

Long, revolving, cylindrical grading reels replaced in some cases the earlier shaker frames. Such a reel consisted of a framework divided equally into four sections, each of which was covered with a wire screen. The screens, which could be replaced, were of various-sized mesh, and by making substitutions the character of the separation could be fairly well controlled. Beneath each section was a trough to receive the rice which passed through the screen of that section. The grading reels are now used only to assist the more efficient cockle cylinders described in the following paragraph.

The cockle cylinder is by far the most valuable and widely used device for grading rice. It is a form of the machine extensively employed in removing cockle from wheat previous to its milling, and has been in use for grading rice for about 10 or 12 years. It consists of a metal cylinder, the inside surface of which contains indentations stamped or bored in the metal. The cylinder is set on an incline and propelled from the outside, and in action revolves around a supporting stationary axle, to which is also fastened an adjustable curved metal apron. The apron extends nearly across the diameter of the cylinder and throughout its entire length. The rice to be graded is introduced on the floor of the cylinder at its upper end. As the cylinder revolves, the smallest particles of rice fall into the depressions, are carried upward through a part of a revolution, and when above the suspended apron, they fall upon it. Since the apron receives all rice particles which are carried by the surrounding cylinder above its edge, the size separation of the rice may be changed at will by adjusting the position of the apron on the axle and thus raising or lowering the edge of the apron. Each cylinder is designated according to the diameter of its depressions, which, as in the case of the flat metal screens, are expressed in terms of sixty-fourths of an inch. In most mills three cockle cylinders, Nos. 10, 12, and 14, are set up in the same framework and are operated together, and frequently two such sets are placed side by side in a double frame. It is the customary practice in milling the Honduras type of rice to conduct the ungraded rice from the shaker frame to the floor of cockle cylinder No. 10, which takes out the smallest particles and sends the remainder to cylinder No. 12 below. Broken grains of the next larger size are separated on the apron of cylinder No. 12 and the remainder goes down to cylinder No. 14, which performs its work in a similar way. The rice from the apron in cylinder No. 10 is ordinarily bagged as the screenings grade of clean rice, the particles from the aprons of Nos. 12 and 14 are mixed and sold as the

second head grade, and the remainder from the floor of No. 14 constitutes the fancy head grade. Each separated grade is conducted through a wooden chute to the first floor of the mill, where it is packed for the market.

The above-described separations apply only to the Honduras type of rice. The Japan type is sorted in a similar way, except that all broken particles separated by the cockle cylinders are ordinarily mixed and sold as Japan type screenings, thus making three grades instead of four.

Weighing and bagging machines.—All clean rice, except the brewer's rice and a small amount which is packed in cartons, is shipped from the mill in closely woven burlap bags, or pockets, of 100 pounds each. In many mills automatic machines for weighing the rice and sewing the filled bags have been installed with satisfactory results.

EFFECTS OF MILLING ON RICE.

It is the purpose of modern rice milling to free the grain from hulls and then to scour and grade it so as to produce a maximum amount of the highly polished rice which, on account of its bright luster, seems to appeal to the trade. The scouring process, to be effective in removing the bran layers, is so severe that a large proportion of the rice grains are broken, the weight of the individual grains is materially decreased, and important chemical constituents are removed.

MECHANICAL EFFECT.

METHOD OF ANALYSIS.

A 25-gram portion of the thoroughly mixed sample was weighed out for the mechanical analysis. This was shaken on a nest of two flat metal screens with round holes six sixty-fourths and five sixty-fourths of an inch in diameter, respectively. The particles which passed through the larger holes, but remained on the screen with the smaller holes, were weighed and considered as one-third grain, while those which also passed through the smaller holes were classified as less than one-third grain. The remainder of the sample was then separated into three further sizes by hand picking with small forceps. The whole grains were first removed and the remainder divided into particles of more and particles of less than one-half grains of the average size occurring in the sample under examination. The weight of each of the five separations was then taken and the results calculated to a percentage. The divisions, according to the size of particles, are therefore (1) whole grains, (2) three-fourth grains, (3) one-half grains, (4) one-third grains, (5) less than one-third grains. While these designations do not describe with abso-

lute accuracy the classes of separated rice, they will serve for comparison and are more convenient for use in the tables which follow than exact descriptions could be. Furthermore, the ideas to be presented are more readily grasped than if the separations were designated merely by consecutive letters or numbers. The weight of 1,000 kernels was determined by counting and weighing 250 of the whole grains, separated as previously described.

BREAKAGE IN MILLING.

Unfortunately no figures are available from the literature which show the breakage of rice in the mortar-and-pestle mills. It is asserted, however, that this breakage was surprisingly small, considering the great weight of the iron-clad pestle. The decline in the use of these mills was undoubtedly due to other economic factors, such as their comparatively small daily output, considering the equipment involved, and their incapacity for fine adjustment to suit varying qualities of rice.

The "plantation hullers," on the other hand, cause great breakage, especially to rice of the Honduras type. The writers have examined samples taken from one lot of the Honduras type and three lots of the Japan type milled in "plantation hullers." Of the Honduras lot samples were secured of the partly milled grain and of the finished product, while the samples of the Japan type all represent the finished milled rice.

In Table III special attention is called to the excessive breakage of the rice. The action of the second hulling as well as the first is shown to be very disastrous to the whole-grain content.

TABLE III.—*Size separation of rice of the Honduras type milled in "plantation hullers."*

Milling stage.	Grains (per cent).				
	Whole.	Three-fourths.	One-half.	One-third.	Less than one-third.
After first hulling.....	32.0	12.7	44.1	7.0	4.2
Finished product.....	9.6	8.8	38.8	24.8	18.0

Fifty-six series of samples of the Honduras type of rice were secured from big modern mills in all parts of the rice-growing belts of Louisiana, Texas, and Arkansas, representing various grades and qualities of rough rice. Table IV, which follows, has been prepared from the figures showing the mechanical analyses of these series. The analytical results for the rough rice have been omitted from the table, as the figures are not easily comparable and have no particular bearing on the phase in question.

TABLE IV.—*Size separation of samples of rice of the Honduras and Japan types from various milling machines in modern mills.*

Milling stage. /	Average of 56 series of the Honduras type of grains (per cent).					Average of 25 series of the Japan type of grains (per cent).				
	Whole.	Three-fourths.	One-half.	One-third.	Less than one-third.	Whole.	Three-fourths.	One-half.	One-third.	Less than one-third.
Paddy machine.....	74.35	8.76	15.33	1.16	0.40	92.38	2.38	4.38	0.65	0.21
Hullers and pearling cone.....	52.51	13.38	24.73	5.67	3.71	84.22	4.30	7.66	2.44	1.38
Brush, brewer's rice:										
In.....	49.96	13.56	25.51	6.54	4.43	80.37	4.89	8.54	3.83	2.37
Out.....	52.57	14.62	26.28	5.11	1.42	82.52	4.84	8.96	2.88	.80
Trumbles.....	51.69	14.44	27.18	5.49	1.20	82.57	4.70	8.29	3.61	.83

The five points in the milling process at which these samples were taken are considered very significant. The first is rice from the paddy machine, and this shows the condition of the grain after the removal of its hull in the stones and the separation in the paddy machine of the remaining portion of rough rice. This, then, is brown rice, retaining the bran coat and germ nearly intact. Naturally, the whole-grain content is comparatively large, but it has been found that badly sun-cracked rice often shows a considerable amount of breakage even at this point.

The second line is rice from the hullers and pearling cone. Inasmuch as the pearling cone performs the same work in some mills as is done by the hullers in others, the results are combined in the table, so that the figures show the condition after the final scouring operation in each case, before the material goes to the brush. The severe scouring which the grain undergoes in these machines is clearly shown by the marked decrease in the percentage of whole grains from that of the previous line. It is at this stage that most of the breakage in rice milling occurs.

The third line shows the rice after it has been scoured by the brush and still contains all the small particles of brewer's rice. The fourth line gives the percentage composition after most of the brewer's rice has been removed in the brewer's reel. It is seen that the brush reduces the whole grain content only about $2\frac{1}{2}$ per cent. On the other hand, a small increase in the percentage of whole grains naturally results from the removal by the brewer's reel of the fine particles of brewer's rice.

The last line shows the ungraded rice as it leaves the trumbles, where it has been rolled and heated after having received in many cases an application of coating materials. A slight breakage has also occurred here. The rice grain normally is hard and brittle and

greatly subject to fracture by a rapid change in temperature. Care is used by the miller to shield, as far as possible, from currents of cool air or from cold metal the rice which has become heated in the brush or trumble.

Twenty-five similar series of the Japan type of rice were secured and analyzed in the same way, and the results are also shown in Table IV. Breakage in milling rice of this type is seen to follow the same lines as shown for the Honduras type, but less injury occurs, on account of the short, compact shape of the grain.

Figure 6 illustrates the most important data given in Table IV.

EFFECT OF WEIGHT PER
THOUSAND KERNELS.

Nine series of samples of rice of the Honduras type and five series of the Japan type from modern mills were analyzed to show the effect of the milling machines on the weight of the kernels. The whole grains were picked from a portion of each sample and the weight of 250 whole grains ascertained in every case. From this the weight per 1,000 kernels was calculated. Attention is called to the marked decrease in weight of the kernels caused by the action of the hullers and pearling cone. Some decrease in weight is caused by the brush, and the slight increase after passage through the brewer's reel is probably due to the removal at that point of a few of the smallest whole grains. The addition of the glucose and talc coating slightly increases the weight of the grains in the trumbles. A com-

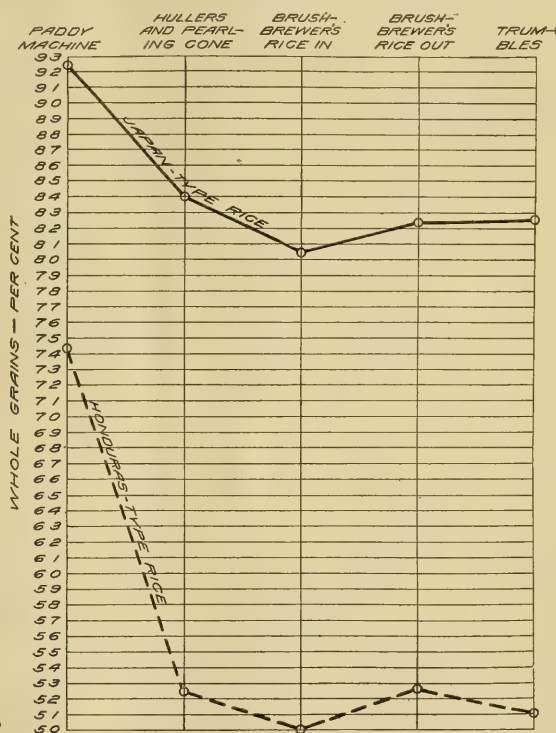


FIG. 6.—Diagram showing the decrease in the percentage of whole grains in the Honduras and Japan types of rice during the course of the milling process.

parison of the relative sizes or weights of the grains of the two types is clearly shown in Table V.

TABLE V.—*Effect of various rice-milling machines on the weight per 1,000 kernels of rice.*

Milling stage.	Average weight of rice samples (grams).	
	Honduras type, 9 samples.	Japan type, 5 samples.
Paddy machine.....	24.13	22.44
Hullers and pearling cone.....	22.80	21.50
Brush, brewer's rice:		
In.....	22.07	20.20
Out.....	22.20	20.40
Trumbles.....	22.35	20.56

Figure 7 illustrates the data contained in Table V and shows the gradual decrease in weight per 1,000 kernels of rice of the Honduras and Japan types as the milling process proceeds.

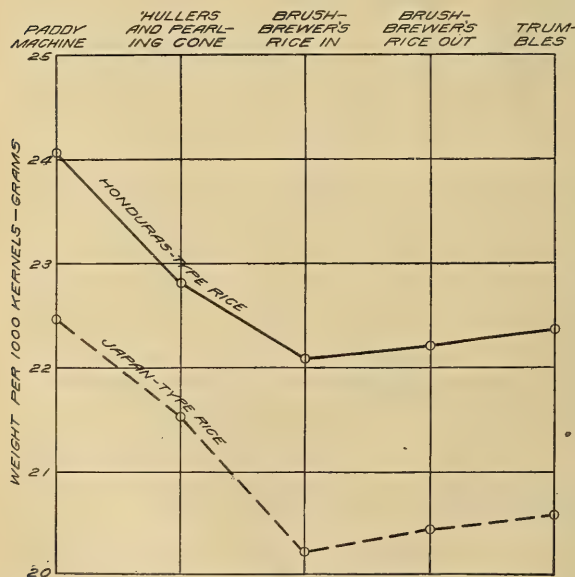


FIG. 7.—Diagram showing the effect of various milling machines on the weight per thousand kernels of the Honduras and Japan types of rice.

CHEMICAL EFFECT.

Figures in Louisiana Agricultural Experiment Station Bulletin 24 (first series), 1889, show the difference in chemical composition of one lot of rice at various stages in the old mortar-and-pestle milling process in Louisiana.

Similar results were obtained by McDonnell (1901), South Carolina Agricultural Experi-

ment Station Bulletin 59, on the product of a South Carolina mill of the same type. Apparently the scouring proceeded further, however, than in the case of the Louisiana mill. The analyses of both lots are shown in Table VI.

The chemical analyses of samples of rice of the Japan type milled in a "plantation huller," also given in Table VI, were made in the Bureau of Chemistry, Department of Agriculture, according to the

methods of the Association of Official Agricultural Chemists. For better comparison, these results are also calculated to the moisture-free basis. They show that the product from the "plantation huller" is lower in percentage of ash, ether extract, and crude fiber than the rice from the old mortar-and-pestle mills, indicating a more thorough scouring of the grains in the huller.

TABLE VI.—*Chemical composition of samples of rice in various stages of milling and of different qualities.*

Sample analyzed.	Constituents (per cent).								
	Mois- ture.	Ash.	Ether extract.	Crude fiber.	Pro- tein.	Calculated to moisture-free basis.			
						Ash.	Ether extract.	Crude fiber.	Pro- tein.
MORTAR-AND-PESTLE MILL.									
Louisiana lot (Honduras type), 1889:									
Rough rice.....	10.95	5.45	2.58	9.28	7.44	6.12	2.89	10.42	8.35
Other stages—									
From hulling stones.	12.12	2.55	2.10	3.03	8.09	2.90	2.39	3.45	9.21
Pounded.....	12.42	2.38	2.50	2.55	8.14	2.72	2.85	2.91	9.29
From cooling floor.	12.75	.82	1.05	.72	7.74	.94	1.20	.83	8.87
Clean.....	12.85	.73	.38	.47	7.52	.83	.44	.54	8.63
South Carolina lot, 1901:									
Rough rice (dried at 50° C.).....	5.21	6.74	2.36	8.07	7.19	7.11	2.49	8.51	7.59
Polished rice—									
Whole.....	12.79	.42	.24	.33	7.38	.48	.27	.38	8.46
“Middling”.....	13.69	.40	.43	.33	6.88	.46	.49	.38	7.97
Small.....	13.92	.51	.73	.39	6.75	.59	.84	.45	7.84
“PLANTATION HULLER.”									
Rice of the Japan type:									
Good quality.....	10.28	.30	.19	.20	7.75	.33	.21	.22	8.64
Fair quality.....	9.96	.32	.23	.25	6.38	.36	.26	.28	7.09
Poor quality.....	10.09	.31	.19	.21	7.00	.34	.21	.23	7.79

Chemical analyses were made of four series of mill samples of Honduras rice and of three series of samples of Japan rice. These samples, which represent different grades of rough stock, were obtained in various parts of Louisiana, Texas, and Arkansas and are considered to typify the chemical effect of rice milling as now exemplified in those States. Table VII gives the results of these chemical analyses.

TABLE VII.—*Chemical composition of the Honduras and Japan types of rice from various milling machines of modern rice mills.*

Type.	Grade.	Constituents (per cent).										
		Moisture.	Ash.	Ether extract.	Crude fiber.	Protein.	Pentosans.	Calculated to moisture-free basis.				
								Ash.	Ether extract.	Crude fiber.	Protein.	Pentosa- s.
RICE OF THE HONDURAS TYPE.												
Series 1:												
Rough rice.....	1	11.35	5.26	1.57	9.05	7.38	6.13	5.93	1.77	10.21	8.32	6.97
From paddy machine.....		12.33	1.13	1.28	1.10	8.06	2.56	1.29	1.46	1.25	9.19	2.92
From hullers.....		12.64	.39	.08	.32	7.63	2.04	.45	.09	.37	8.73	2.33
From pearling cone.....		11.91	.35	.08	.32	7.63	1.72	.40	.09	.36	8.66	1.95
From brush, brewer's rice, out.....		10.80	.34	.24	.31	7.63	1.98	.38	.27	.35	8.55	2.22
From trumbles, uncoated.....		11.82	.36	.21	.20	7.44	1.71	.41	.24	.23	8.44	1.94
Series 2:												
Rough rice.....	1	10.81	5.75	1.48	9.16	7.66	6.21	6.45	1.66	10.27	8.59	6.96
From paddy machine.....		12.40	1.31	2.00	.95	9.22	2.61	1.50	2.28	1.08	10.52	2.98
From brush, brewer's rice, out.....		12.26	.35	.15	.35	8.41	1.91	.40	.17	.40	9.59	2.18
Series 3:												
Rough rice.....	1	12.42	4.63	1.31	7.00	7.56	5.12	5.28	1.50	7.99	8.63	5.85
From paddy machine.....		13.18	1.21	1.70	.78	8.75	2.10	1.39	1.96	.90	10.08	2.40
From hullers.....		13.08	.80	.58	.46	8.12	1.68	.92	.67	.53	9.34	1.93
From pearling cone.....		13.09	.58	.47	.28	8.12	1.34	.67	.54	.32	9.34	1.54
From brush, brewer's rice, out.....		13.23	.43	.26	.19	8.43	1.40	.50	.30	.22	9.72	1.61
From trumbles, uncoated.....		13.09	.48	.28	.25	7.93	1.35	.55	.32	.29	9.12	1.55
Series 4:												
Rough rice.....	5	10.49	5.97	1.96	9.58	7.31	6.10	6.67	2.19	10.70	8.17	6.81
From paddy machine.....		11.38	1.06	2.20	1.14	8.25	2.39	1.20	2.48	1.29	9.31	2.70
From hullers.....		11.96	.40	.55	.38	7.63	1.99	.45	.62	.43	8.67	2.26
From brush, brewer's rice, out.....		11.26	.33	.34	.35	7.75	1.90	.37	.38	.39	8.73	2.14
From trumbles, coated.....		11.16	.35	.33	.33	7.88	1.92	.39	.37	.37	8.87	2.16
Average of the four series:												
Rough rice.....		11.27	5.40	1.58	8.67	7.48	5.90	6.08	1.78	9.79	8.43	6.65
From paddy machine.....		12.32	1.18	1.79	.99	8.57	2.42	1.35	2.05	1.13	9.78	2.75
From hullers.....		12.56	.53	.40	.39	7.79	1.90	.61	.46	.44	8.91	2.17
From pearling cone.....		12.50	.47	.28	.30	7.88	1.53	.54	.32	.34	9.00	1.75
From brush.....		11.89	.36	.25	.30	8.06	1.80	.41	.28	.34	9.15	2.04
From trumbles.....		12.02	.40	.21	.26	7.75	1.66	.45	.31	.30	8.81	1.88
Loss, paddy machine to trumbles.....								66.00	85.00	73.00	10.00	32.00
RICE OF THE JAPAN TYPE.												
Series 1:												
Rough rice.....	1	10.72	5.36	1.78	7.68	6.31	5.51	6.00	1.99	8.60	7.07	6.17
From paddy machine.....		11.96	1.13	1.92	.86	7.09	2.63	1.28	2.18	.98	8.05	2.99
From hullers.....		12.20	.81	1.32	.56	7.00	2.03	.92	1.50	.64	7.97	2.31
From pearling cone.....		12.71	.51	.57	.39	6.59	1.86	.58	.65	.45	7.55	2.13
From brush, brewer's rice, out.....		12.17	.29	.09	.33	6.66	1.99	.33	.10	.38	7.58	2.27
From trumbles, coated.....		12.27	.31	.26	.36	6.16	1.66	.35	.30	.41	7.02	1.89

TABLE VII.—*Chemical composition of the Honduras and Japan types of rice from various milling machines of modern rice mills—Continued.*

Type.	Grade.	Constituents (per cent).										
		Moisture.	Ash.	Ether extract.	Crude fiber.	Protein.	Pentosans.	Calculated to moisture-free basis.				
								Ash.	Ether extract.	Crude fiber.	Protein.	Pentosans.
RICE OF THE JAPAN TYPE—continued.												
Series 2:												
Rough rice.....	3	11.15	4.57	1.80	7.81	7.00	5.73	5.14	2.03	8.79	7.88	6.45
From paddy machine.....		12.83	1.12	1.69	.96	7.81	2.60	1.23	1.82	1.10	8.96	2.98
From hullers.....		13.02	.56	.47	.40	7.16	1.91	.64	.54	.46	8.23	2.20
From pearling cone.....		12.87	.36	.18	.31	7.06	1.94	.41	.21	.36	8.10	2.22
From brush, brewer's rice, out.....		12.41	.31	.40	.38	7.06	1.73	.35	.46	.43	8.06	1.97
From trumbles, coated.....		11.55	.32	.06	.34	7.19	2.12	.36	.07	.38	8.02	2.40
Series 3:												
Rough rice.....	5	11.27	5.48	1.65	8.30	6.88	5.21	6.18	1.86	9.35	6.96	5.87
From paddy machine.....		12.35	1.14	.95	.72	6.81	1.61	1.30	1.08	.82	7.77	1.84
From hullers.....		15.87	.72	.20	.31	6.31	1.34	.86	.24	.39	7.50	1.59
From pearling cone.....		14.55	.33	.18	.16	6.12	.99	.39	.21	.19	7.16	1.16
From brush, brewer's rice, out.....		13.88	.35	.16	.16	6.12	1.11	.41	.19	.19	7.11	1.29
From trumbles, uncoated.....		13.68	.39	.24	.17	6.06	1.26	.45	.28	.20	7.02	1.46
Average of the three series:												
Rough rice.....		11.05	5.14	1.74	7.93	6.50	5.48	5.77	1.96	8.91	7.30	6.16
From paddy machine.....		12.38	1.13	1.52	.85	7.24	2.28	1.29	1.69	.97	8.26	2.60
From hullers.....		13.70	.70	.66	.42	6.82	1.76	.81	.76	.50	7.90	2.03
From pearling cone.....		13.38	.40	.31	.29	6.59	1.60	.46	.36	.33	7.60	1.84
From brush.....		12.82	.32	.22	.29	6.61	1.68	.36	.25	.33	7.58	1.84
From trumbles.....		12.50	.34	.19	.29	6.47	1.68	.39	.22	.33	7.35	1.92
Loss, paddy machine to trumbles.....								70.00	87.00	66.00	12.00	26.00

A careful study of the averages of the Honduras type of rice, calculated to a moisture-free basis, is significant and interesting. The ash content is reduced very markedly when the hulls are removed, and one-half of the ash which remains is removed by the scouring work of the hullers. During the remainder of the process the decrease is gradual. The total loss by the scouring process, that is, from paddy machine to trumbles, is 66 per cent, or two-thirds of the ash of the hulled rice.

The percentage of ether extract or fat is generally increased by the removal of the hulls, since the fat or oil is located principally in the eye, or germ, of the grain. However, if the stones are not properly adjusted, it sometimes happens that a portion of the germ is broken off at this time, thereby causing the fat content of the hulled rice to be lower than that of the rough rice. The fat content of

the hulled rice is reduced more than three-fourths in the hullers, but through the remainder of the process the reduction is gradual and small. The total loss of fat in scouring is 85 per cent.

The crude-fiber content of the rice is reduced 88 per cent when the hulls are removed, and 73 per cent of the remainder is lost during the process of scouring.

The protein figure rises on the removal of the hulls, as was the case with the fat content. It is especially worthy of notice that only 10 per cent of the protein present in the hulled grain is lost in scouring. This has already been explained by the fact that the protein-

bearing aleurone layer is not removed during scouring and that the protoplasm which contains protein is disseminated throughout the starchy portion of the endosperm.

Approximately 60 per cent of the pentosan content is removed with the hulls, and 32 per cent of the remainder is lost during the process of scouring.

The loss of the various chemical ingredients of rice of the Japan type corresponds closely to that given for that of the Honduras type.

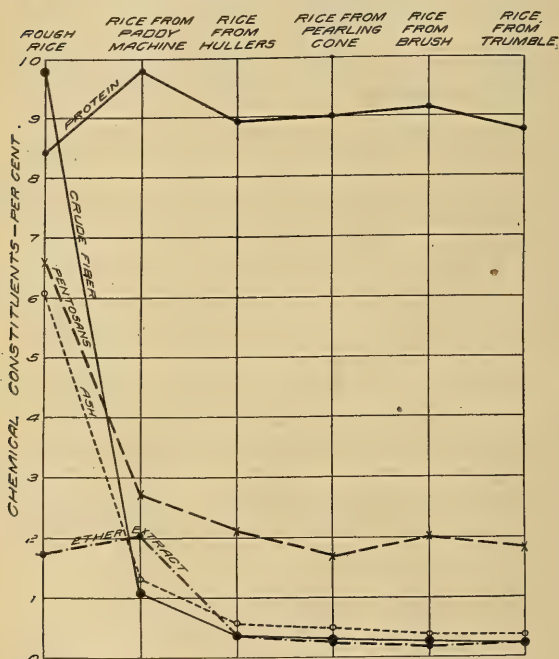


FIG. 8.—Diagram showing the effect of modern rice milling machines on the ash, ether-extract, crude-fiber, protein, and pentosan content of rice of the Honduras type.

Figures 8 and 9 illustrate the data contained in the averages of Table VII, calculated to a moisture-free basis.

MILLED RICE AND ITS BY-PRODUCTS.

MECHANICAL ANALYSES AND MILL YIELDS.

The grading devices employed in the modern rice mill permit the milled rice to be separated according to the size of the particles into almost any character of grades desired. Mill and trade practice, however, has outlined roughly six grades of the Honduras type and three grades of the Japan type, based entirely, or nearly so, on the

size of the particles or the percentage of whole grains. Several other factors affect the commercial value of various lots within the same grade. These factors in relative importance are (1) color, (2) proportion of grains damaged by heat or by insects, (3) presence of weed seeds, and (4) presence of unhulled, or paddy, rice grains. For the purpose of this paper, only the size separations will be considered.

RICE OF THE HONDURAS TYPE.

The commercial grades of the Honduras type of rice generally now made in the mills are (1) extra fancy head or triple-screened rice (made only when the rough rice is of exceptionally good quality); (2) fancy head, or "head" rice; (3) second head rice; (4) screenings; (5) brewer's rice; and (6) line (ungraded) rice. These designations are commonly used in rice mills, and less commonly by produce exchanges in their quotations. They are strictly trade terms in origin and in use and are not the result of any ruling by the Department of Agriculture.

The graded samples of rice which are about to be described were secured during 1912 and 1913 from all parts of the rice-growing sections of Louisiana, Texas, and Arkansas. They were obtained principally from mills, but a few came from rice brokers and other sources. Mechanical analyses were made of the samples secured, in the same way as previously described for the samples from the milling machines.

The grade known as extra fancy head, also known as triple screened, is rarely made and is not one of the common commercial grades. The mill yield approximates 30 pounds per barrel of 162 pounds of rough rice. The results of analyses of the samples of this grade are given in Table VIII.

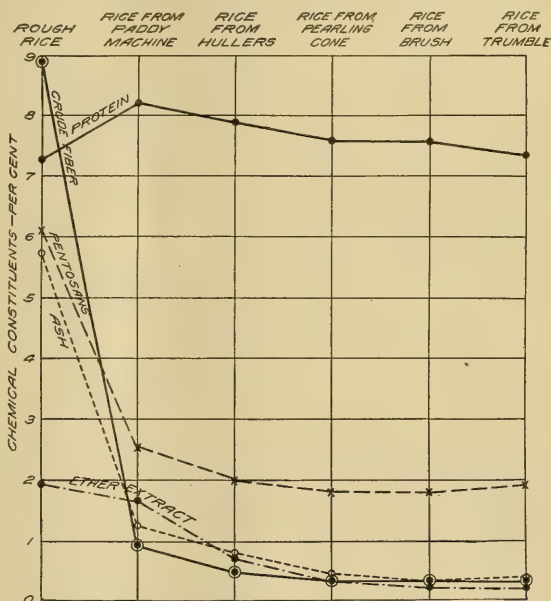


FIG. 9.—Diagram showing the effect of modern rice milling machines on the ash, ether-extract, crude-fiber, protein, and pentosan content of rice of the Japan type.

Seventy-five samples of the fancy head, or "head," rice, as it is also termed, were secured. The mill yield of this grade varies from 45 to 85 pounds per barrel of rough rice, with an average of about 59 pounds when no extra fancy head grade is made. The results of the analyses are given in Table VIII.

Table VIII also shows that the second head grade is composed principally of half grains, but contains also a large percentage of three-fourths grains. The mill yield varies from 10 to 30 pounds per barrel of rough rice, with an average of 19 pounds.

TABLE VIII.—*Size separation of rice of the Honduras type.*

Separations.	Extra fancy head, or triple-screened, grade (9 samples).			Fancy head, or "head," grade (75 samples).			Second head grade (48 samples).		
	Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.
Whole grains.....per cent..	89.96	96.80	82.00	81.28	94.40	42.80	1.82	7.60	0
Three-fourths grains....do....	8.49	14.40	2.40	13.11	36.80	4.40	21.47	58.80	3.20
One-half grains.....do....	1.51	4.80	0	5.40	34.40	0	70.69	93.60	36.00
One-third grains.....do....	.04	.40	0	.20	4.00	0	5.64	23.60	.40
Less than one-third grains, per cent.....	0	0	0	.01	.40	0	.38	1.60	0

Separations.	Screenings grade (48 samples).			Brewer's grade (53 samples).			Line grade (9 samples).		
	Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.
Whole grains.....per cent..	0.71	7.60	0	0.26	1.60	0	53.91	64.80	30.80
Three-fourths grains....do....	4.23	24.00	0	.22	2.20	0	14.31	22.40	8.40
One-half grains.....do....	56.08	81.20	10.00	2.89	26.40	0	27.25	46.40	18.80
One-third grains.....do....	32.59	63.60	7.60	26.28	81.80	2.40	4.00	12.40	.80
Less than one-third grains, per cent.....	6.39	44.40	0	70.35	97.60	14.80	.53	2.00	0

The screenings grade contains principally half grains, but differs from second head rice in that it contains but few three-fourths grains and a large proportion of one-third grains. The mill yield varies from 5 to 25 pounds per barrel of rough rice, with an average of 15 pounds. The figures for this grade are given in Table VIII.

The brewer's rice grade contains the smallest particles of milled rice and is composed almost entirely of pieces less than one-third of a grain in size. The mill yield varies from 3 to 13 pounds per barrel of rough rice, with an average of 8 pounds. The results of the analyses are given in Table VIII.

The mill yield of line rice approximates 89 pounds per barrel of rough rice, and the grade includes all the clean product except brewer's rice. As would be expected, there is a very wide variation in the proportions of the particles of different sizes in this grade. Table VIII gives the results of the analyses.

RICE OF THE JAPAN TYPE.

The commercial grades of the Japan type of rice generally now made in the mills are (1) fancy head, or "head," rice; (2) screenings; (3) brewer's rice. Samples of this type of rice were obtained from the same sources and the analyses performed in the same way as previously described for rice of the Honduras type. Fancy head rice is composed very largely of whole grains. The whole-grain percentage is larger than in the corresponding grade of the Honduras type, because the shape of the kernels of the Japan type is more nearly round; consequently, there is a smaller amount of breakage. The mill yield of this commercial grade varies from 92 to 105 pounds per barrel of rough rice and averages 96 pounds. Table IX gives the analytical results for this grade.

TABLE IX.—*Size separation of rice of the Japan type.*

Separations.	Fancy head, or "head," grade (75 samples).			Screenings grade (18 samples).			Brewer's grade (18 samples).		
	Aver- age.	Maxi- mum.	Mini- mum.	Aver- age.	Maxi- mum.	Mini- mum.	Aver- age.	Maxi- mum.	Mini- mum.
Whole grains.....per cent..	90.43	98.40	76.40	4.58	18.80	0	0.93	11.00	0
Three-fourths grains.....do....	3.45	15.60	1.20	11.89	26.40	0	.36	2.80	0
One-half grains.....do.....	5.08	16.80	0	50.11	70.00	26.40	3.53	16.00	0
One-third grains.....do.....	.50	2.80	0	30.30	54.80	3.20	29.11	76.40	1.80
Less than one-third grains, per cent.....	.04	.40	0	3.12	12.40	0	66.07	98.20	16.80

The only commercial grade of broken Japan-type rice used as such for food is that of screenings. The results of mechanical analyses given in Table IX show that it is very similar to Honduras screenings, but the yield is much smaller. In commercial practice the two are often mixed. The mill yield varies from 3 to 11 pounds per barrel of rough rice and averages 5 pounds.

Japan-type brewer's rice is not distinguished commercially from Honduras brewer's rice, and the two are used interchangeably to supply the trade. The mill yield varies from 3 to 10 pounds per barrel of rough rice, with an average of 5 pounds. The analytical results from the samples of this grade are given in Table IX.

BY-PRODUCTS.

The mill yield of rice bran varies with the severity of scouring and the texture of the rice, and approximates 22 pounds per barrel of 162 pounds of rough rice of the Honduras type and 20 pounds for the Japan type. Rice polish approximates in yield 6 pounds per barrel of rough rice for both the Honduras and the Japan types, but, like the bran, it varies considerably with mill practice and

the character of the grain. Rice hulls and the intangible mill loss together amount to about 33 pounds for rice of the Honduras type and 30 pounds for the Japan type. The hulls on the Honduras type of kernel are somewhat heavier in proportion than those on the Japan type of grain.

TABLE X.—Yield of cleaned rice by grades and of by-products obtained from the milling of 1 barrel of rough rice of 162 pounds.

Cleaned rice and by-products.	Average yield (pounds).	
	Honduras type.	Japan type.
Fancy head, or "head".....	59	96
Second head.....	19	
Screenings.....	15	5
Brewer's rice.....	8	5
Total cleaned rice.....	101	106
Bran.....	22	20
Polish.....	6	6
Hulls and milling loss.....	33	30
Total by-products and milling loss.....	61	56

Figure 10 illustrates the data given in Table X and shows the proportions of the various products resulting from rice milling.

CHEMICAL ANALYSES.

Table XI gives the chemical composition of the clean-rice products from the corresponding series recorded in Table VII. For comparison, these results are also calculated to a moisture-free basis

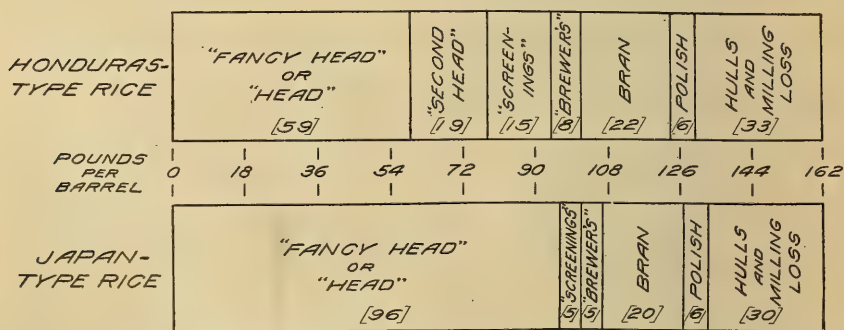


FIG. 10.—Diagram showing the average yield in pounds of cleaned rice, by grades, and of by-products obtained from the milling of a barrel of rough rice of 162 pounds.

and averages have been made for each commercial grade. The figures are practically the same as those already given for the composition of the ungraded rice from the trumbles in each corresponding series. Attention is called to the slightly smaller percentage of ash, ether

extract, and crude fiber in the higher than in the lower or broken-rice grades of both the Honduras and the Japan types of rice. The protein figure for the milled rice of the Honduras type appears to be somewhat higher than that for the Japan type. This may be due to the greater length of the grain of the former and the consequent greater surface of the kernel, and therefore to the larger surface area of the protein-bearing aleurone layer. As previously stated, a considerable portion of this layer remains on the grain after milling.

TABLE XI.—*Chemical composition of samples of milled graded rice of the Honduras and Japan types in series corresponding to those in Table VII.*

Type and series.	Constituents (per cent).										
	Mois- ture.	Ash.	Ether ex- tract.	Crude fiber.	Pro- tein.	Pen- to- sans.	Calculated to moisture-free basis.				
							Ash.	Ether ex- tract.	Crude fiber.	Pro- tein.	Pen- to- sans.
RICE OF THE HONDURAS TYPE.											
Series 1:											
Fancy head, uncoated.....	12.05	0.33	0.17	0.21	7.69	1.94	0.38	0.19	0.24	8.74	2.20
Second head, uncoated.....	11.92	.33	.17	.26	7.31	1.94	.37	.19	.30	8.30	2.20
Screenings, uncoated.....	12.32	.48	.22	.25	7.31	1.91	.55	.25	.28	8.34	2.21
Brewer's rice.....	11.13	.65	.26	.30	7.50	1.85	.73	.29	.34	8.44	2.09
Series 2:											
Fancy head, uncoated.....	12.49	.31	.28	.34	8.75	1.73	.35	.32	.39	10.00	1.98
Second head, uncoated.....	12.01	.30	.35	.33	8.31	1.54	.34	.40	.37	9.44	1.75
Screenings, uncoated.....	12.75	.34	.37	.30	8.38	1.98	.39	.42	.34	9.60	2.27
Brewer's rice.....	12.48	.41	.21	.41	8.10	1.81	.47	.24	.47	9.26	2.07
Series 3:											
Fancy head, uncoated.....	12.32	.39	.24	.21	8.43	1.45	.44	.27	.27	9.61	1.65
Second head, uncoated.....	12.14	.44	.27	.24	8.06	1.24	.50	.31	.27	9.17	1.41
Screenings, uncoated.....	13.46	.60	.29	.24	7.75	1.44	.69	.33	.28	8.96	1.66
Brewer's rice.....	13.64	.88	.37	.34	8.12	1.54	1.02	.43	.39	9.40	1.78
Series 4:											
Fancy head, coated.....	11.66	.34	.23	.30	7.88	1.79	.38	.26	.34	8.92	2.03
Second head, coated.....	11.75	.39	.28	.33	7.81	1.95	.44	.32	.37	8.85	2.21
Screenings, coated.....	12.48	.46	.46	.33	7.31	1.86	.53	.53	.38	8.35	2.13
Brewer's rice.....	11.78	.53	.48	.43	7.50	2.03	.60	.54	.49	8.50	2.30
Average of the four series:											
Fancy head.....	12.13	.34	.23	.27	8.19	1.75	.39	.26	.30	9.32	1.97
Second head.....	11.96	.37	.27	.29	7.87	1.67	.41	.31	.33	8.94	1.89
Screenings.....	12.75	.47	.34	.28	7.69	1.80	.54	.38	.32	8.81	2.07
Brewer's rice.....	12.26	.62	.33	.37	7.81	1.81	.71	.38	.42	8.40	2.06
RICE OF THE JAPAN TYPE.											
Series 1:											
Head, coated.....	12.24	.34	.18	.33	6.22	1.77	.39	.20	.38	7.09	2.02
Screenings, coated.....	12.37	.39	.22	.37	6.25	1.69	.45	.25	.42	7.13	1.93
Brewer's rice.....	12.12	.39	.30	.39	6.16	1.70	.44	.34	.44	7.01	1.93
Series 2:											
Head, coated.....	12.17	.32	.07	.35	6.78	1.89	.36	.08	.40	7.72	2.15
Screenings, coated.....	12.23	.46	.13	.36	6.94	1.86	.52	.15	.41	7.91	2.12
Brewer's rice.....	12.70	.42	.08	.31	6.69	1.81	.48	.09	.36	7.66	2.07
Series 3:											
Head, coated.....	13.74	.44	.22	.18	5.88	1.45	.51	.25	.21	6.82	1.68
Screenings, coated.....	13.94	.50	.33	.19	6.44	1.60	.58	.38	.22	7.49	1.86
Brewer's rice.....	12.76	.41	.33	.24	7.00	1.40	.47	.38	.27	8.02	1.60
Average of the three series:											
Head.....	12.72	.37	.16	.29	6.29	1.70	.42	.18	.33	7.21	1.95
Screenings.....	12.85	.45	.23	.31	6.54	1.72	.52	.26	.35	7.51	1.97
Brewer's rice.....	12.53	.41	.24	.31	6.62	1.64	.46	.27	.36	7.56	1.87

It is evident from a study of the milling process that no important variation in chemical composition in the rice, except for the addition of a small percentage of glucose and talc, takes place after the grain leaves the brush. It is at this point that the distinction is made between coated and uncoated (erroneously called polished and unpolished) rice. The former receives an addition of a small amount of glucose and talc in the trumbles, while the latter is bagged without such a coating. The fact should be kept in mind that these two products are entirely different from the brown rice from the paddy machine, both in appearance and in chemical composition. The greater proportion of ash, ether extract, crude fiber, protein, and

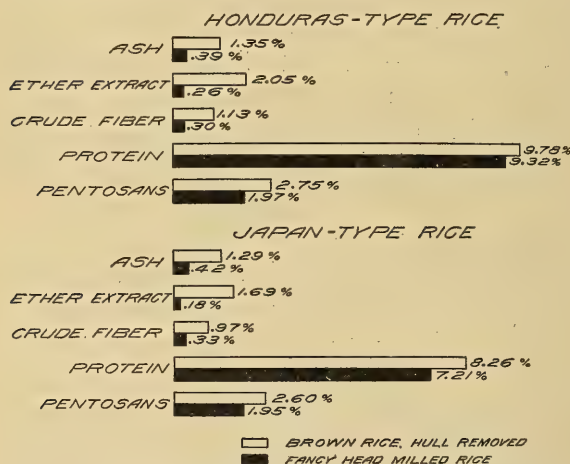


FIG. 11.—Diagram showing a comparison of the chemical composition of brown rice from the paddy machine with that of the corresponding fancy head grade of milled rice.

pentosans found in brown rice, as compared to the quantity in the corresponding milled rice, is graphically shown in figure 11, prepared from data given in Tables VII and XI.

CHEMICAL ANALYSES OF BY-PRODUCTS.

Rice hulls are now considered of little value, if not positively harmful, as a stock feed. There is a limited market for

them as a packing material at about \$4 per ton, but by far the greater portion is burned to furnish power for the rice mills.

Rice bran, when fresh and free from hulls, is an excellent stock feed, but on account of its high fat content it is liable to become rancid and therefore unpalatable to cattle in warm weather. It is also frequently attacked by weevils and other insects if stored in warehouses infested by them.

Rice polish is a highly nutritious flour and is used in the United States as a stock feed. Like bran, it is susceptible to insect attack and becomes rancid in a warm climate.

The accumulation of weed seeds mixed with small amounts of rice and sweepings from the mill is generally sold locally as chicken feed. Such material may amount in exceptional cases to 15 per cent, but the usual figure is probably less than 1 per cent.

Table XII gives the chemical composition of samples of rice hulls, bran, and polish secured by the writers at various mills. Attention is called to the very high content of ash, crude fiber, and pentosans and the corresponding low figure for ether extract and protein in rice hulls.

TABLE XII.—*Chemical composition of rice hulls, bran, and polish.*

By-product, type, and grade.	Constituents (per cent).										
	Mois- ture.	Ash.	Ether ex- tract.	Crude fiber.	Pro- tein.	Pento- sans.	Calculated to moisture-free basis.				
							Ash.	Ether ex- tract.	Crude fiber.	Pro- tein.	Pento- sans.
Hulls:											
Honduras No. 1.....	6.96	20.73	0.22	42.00	1.56	20.24	22.28	0.24	45.14	1.68	21.75
Do.....	6.28	16.67	.78	29.98	3.56	16.11	17.79	.83	32.00	3.80	17.19
Japan No. 5.....	6.12	20.10	.86	36.08	2.69	18.14	21.41	.92	38.43	2.86	19.32
Average.....	6.45	19.17	.62	36.02	2.60	18.16	20.49	.66	38.52	2.78	19.42
Bran:											
Honduras No. 1.....	9.32	10.79	8.53	12.49	13.13	10.16	11.90	9.41	13.69	14.48	11.20
Do.....	9.91	10.37	12.77	10.92	13.69	9.74	11.51	14.17	12.12	15.19	10.81
Japan No. 1.....	9.39	11.33	15.13	12.54	12.81	11.40	12.50	16.70	13.84	14.14	12.58
Average.....	9.54	10.83	12.14	11.95	13.21	10.43	11.97	13.42	13.21	14.60	11.53
Polish:											
Honduras No. 1.....	7.88	5.71	10.97	3.74	12.56	4.58	6.23	11.91	4.06	13.63	4.97
Do.....	8.67	7.02	10.70	2.82	13.06	4.37	7.69	11.72	3.09	14.30	4.78
Japan No. 1.....	10.03	4.96	10.30	1.68	11.56	3.59	5.51	11.45	1.87	12.85	3.99
Japan No. 5.....	7.37	5.67	7.28	2.34	11.25	8.92	6.12	7.86	2.53	12.14	4.23
Average.....	8.49	5.84	9.81	2.65	12.11	4.12	6.38	10.73	2.89	13.23	4.50

SUMMARY.

During the past quarter of a century the important rice-growing area of the United States has shifted from the South Atlantic coast to the Gulf States west of the Mississippi River and to the prairies of Arkansas. Of the 1913 crop, valued on the farm at \$22,090,000, approximately 45 per cent was grown in Louisiana, 38 per cent in Texas, and 15 per cent in Arkansas. Greatly increased production has been accomplished by the enlargement of mills and the improvement of milling methods.

The rice grain from the farm is covered with a hard, siliceous hull. The hulled grain contains a germ, or embryo, located near one end, and is covered with a light-brown bran coat which, when examined under the microscope, is found to consist of seven layers. During the process of milling, the hulls, the germ, six of the bran layers, and a portion of the seventh are removed.

A study of the evolution of rice milling in the United States shows that the farm method of pounding the grain in a wooden mortar with a pestle by hand was the earliest process. This was succeeded

by milling plants employing mechanical power for operating the machinery. Mortars and pestles were enlarged, and screens, fans, polishing brushes, and hulling stones were introduced. In Louisiana small iron "plantation hullers" were used to scrape or scour off the hulls and the bran coats in a single operation.

With two or three exceptions, the 55 modern rice mills of the United States in operation in 1914 were located in Louisiana, Texas, and Arkansas. Various complex machines clean and scour the rice and prepare it for the market. Screens and fans remove the foreign material from the rough rice, which is then hulled between large revolving stones. Fans blow out the loose hulls and paddy machines separate the grain not hulled by the first treatment with the stones. Hullers, pearling cones, and brushes scour from the hulled grain the light-brown bran coat, which is separated in a powdery form through fine wire screens. In the trumbles the rice often receives a coating of glucose and talc approximating two-tenths of 1 per cent of the former and one-tenth of 1 per cent of the latter. The coating materials and the friction in the trumbles produces a bright luster. Grading the milled rice according to the size of particles is effected by shaker frames fitted with screens having perforations of various sizes; by reels, the sections of which are covered with wire of different sizes; and by cockle cylinders, which in revolving pick up the broken pieces in depressions in their inner surfaces and deposit them upon an inclosed apron suspended from the stationary axle. The various grades are bagged separately in pockets of 100 pounds each.

Excessive breakage occurs when rice of the Honduras type is milled in a "plantation huller," and the finished product may have less than 10 per cent of whole grains. The Honduras type of rice milled in a modern plant is broken to a considerable extent during the scouring process, which reduces its whole-grain content from 75 per cent as it leaves the paddy machine to 50 per cent as it leaves the brush. The Japan type of rice, on account of its shape, is broken to a less extent, and under similar conditions averages 92 per cent and 80 per cent, respectively, of whole grains.

Approximately 10 per cent of the weight of the rice kernels of both Honduras and Japan types is removed by the scouring off of bran coat and germ. In other words, the average weight per thousand kernels of rice of the Honduras type is reduced from 24.1 to 22.8 grams by the action of the hullers and pearling cone, and then to 22.1 grams by the brush. The hullers and pearling cone reduce the weight of the grain of Japan rice from 22.4 to 21.5, and the brush further reduces the weight to 20.2 grams.

Chemical analyses show that the old mortar-and-pestle mills removed a somewhat smaller proportion of ash, ether extract, and crude

fiber from the grain than was the case with the "plantation huller" or than is done in the modern mill.

In the modern mill the brown rice from the paddy machine loses a considerable proportion of certain of its constituents in its passage through the scouring machines. There is thus removed from the brown rice about 70 per cent of its ash, 85 per cent of its fat or oil, 70 per cent of its crude fiber, 10 per cent of its protein, and 30 per cent of its pentosans.

The grading of milled rice is based largely on the percentage of whole grains or the size of particles. The four commercial grades of the Honduras type of rice generally made are (1) fancy head, or "head," (2) second head, (3) screenings, and (4) brewer's rice. Other grades sometimes made are extra fancy head, or triple-screened, and line rice. The whole-grain content of the fancy head grade averages about 80 per cent and its mill yield 59 pounds per barrel of rough rice. Second head, screenings, and brewer's rice are largely broken grains of different sizes, and their average yield is 19, 15, and 8 pounds, respectively.

Three commercial grades of the Japan type of rice are generally made. These are (1) fancy head, or "head," (2) screenings, and (3) brewer's rice, with mill yields approximating 96, 5, and 5 pounds per barrel, respectively. The fancy head grade averages 90 per cent of whole grains; the other grades are similar to the corresponding separations produced from the Honduras type of rice.

The mill yield of rice hulls approximates 30 pounds, of rice bran 20 pounds, and of rice polish 6 pounds per barrel of rough rice.

Chemical analyses of the several samples representing various commercial grades of rice show a slightly smaller percentage of ash, ether extract, and crude fiber in the higher than in the corresponding lower or more broken grades of both Honduras and Japan types of rice. The percentage of protein in the milled Honduras type of rice appears to be somewhat higher than that in milled Japan rice.

Rice hulls contain but little ether extract or protein, but are very high in ash, crude fiber, and pentosans. Bran and polish are rich in fat and protein, and when fresh and not adulterated with hulls are considered an excellent stock feed.

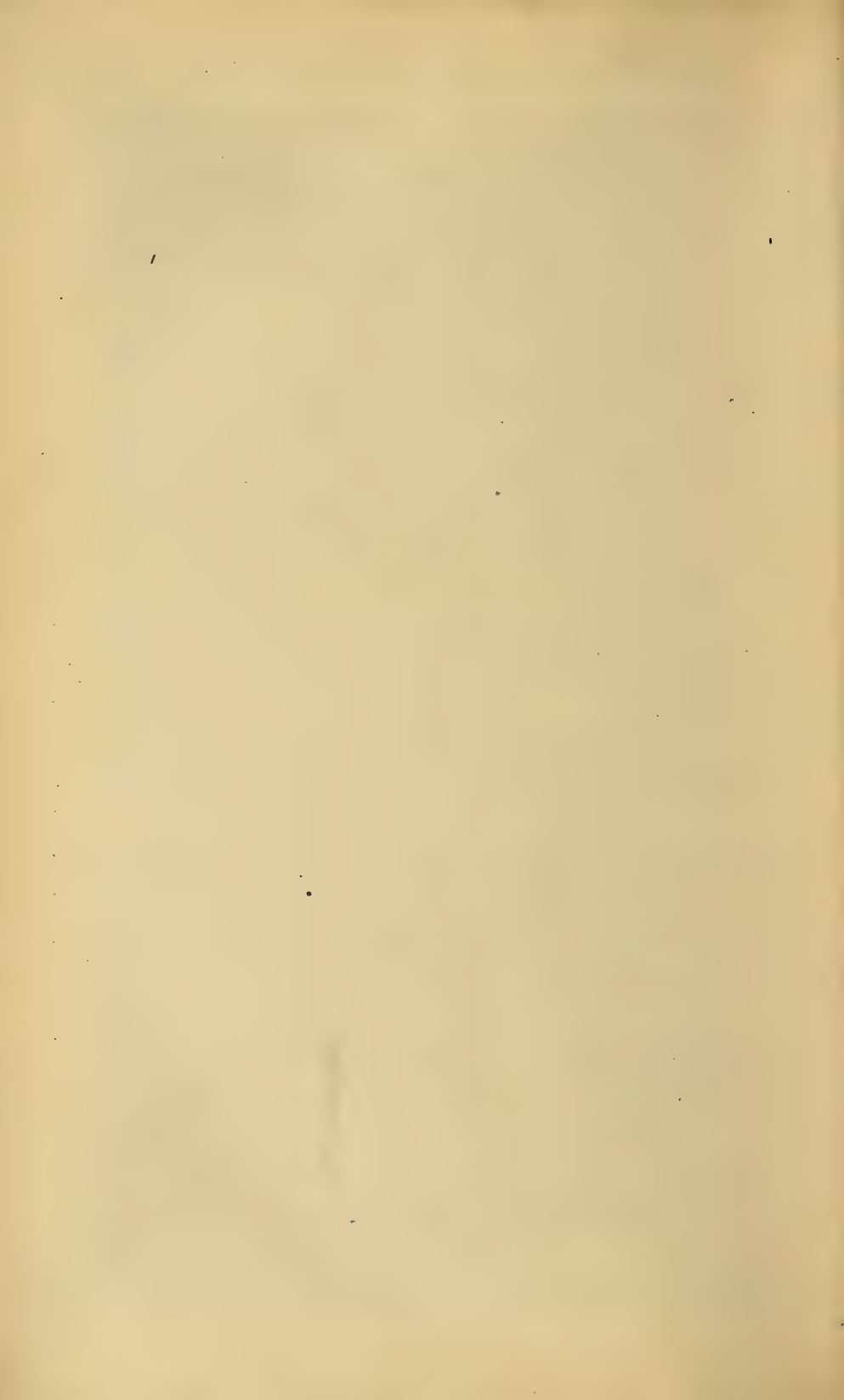
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UNITED STATES DEPARTMENT OF AGRICULTURE



BULLETIN No. 331

Contribution from the Bureau of Plant Industry
WM. A. TAYLOR, Chief



Washington, D. C.



January 10, 1916

THE HANDLING AND SHIPPING OF FRESH CHERRIES AND PRUNES FROM THE WILLAMETTE VALLEY.¹

By H. J. RAMSEY,

Pomologist in Charge of Fruit Handling and Storage Investigations.

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INTRODUCTION.

There is a large bearing acreage of prunes in the district adjacent to Salem, Oreg., as well as in the Willamette Valley generally, and during the last few years there has been planted a considerable acreage of cherries. As a general rule, the prunes are nearly all evaporated, while the cherries are usually canned or put up in barrels for maraschino purposes. Only a small percentage of the cherry crop is evaporated. The economic and crop conditions are such that during certain seasons it would be a distinct advantage to market a portion of the crop in a fresh state instead of evaporating or canning almost the entire product, as is the case at the present time. Many attempts have been made to ship both fresh prunes and cherries to eastern markets, but with indifferent success. Great difficulty has been encountered in shipping from this section for any considerable distance any of these fruits in a green state.

The problem is rendered particularly difficult and acute because of the very humid climate of this section and the frequent rains during both the cherry and prune harvesting seasons. The Willamette Val-

¹ B. B. Pratt and A. W. McKay, formerly pomologists in fruit handling and storage investigations, and G. M. Darrow and G. W. Dewey, of the Office of Horticultural and Pomological Investigations, were all actively engaged in the prosecution of these investigations.

NOTE.—This bulletin will be of interest to fruit growers in the Willamette Valley and similar sections.

ley is on the west side of the Cascade Range, and the climate is considerably more humid than in most of the other fruit-producing sections on the Pacific coast. Because of this humid climate and the frequent rains during the harvesting season, both cherries and prunes may split or crack badly before or at maturity, and oftentimes they are attacked by brown-rot, so common in peaches and stone fruits in different sections of the country.

During the season of 1911 an investigation of the relationship of handling and precooling to the behavior of sweet cherries and prunes in transit to the market was commenced at Salem, Oreg. The work was undertaken in response to urgent requests from the Salem Fruit Union, a cooperative marketing organization of growers at that time handling most of the prunes grown in this district, as well as most of the cherries marketed in a fresh condition. The Department of Agriculture had the hearty cooperation of the members of this association and the growers generally. The Salem Fruit Union constructed in their warehouse at Salem a small precooling plant designed by the department. This plant was put at the disposal of the department, giving most excellent facilities for experimental work in the handling and precooling of various deciduous fruits. Because of the cooperation mentioned and the facilities offered in the way of precooling equipment, Salem was considered an ideal place for experiments in both the handling and precooling of such fruits as prunes and sweet cherries.

PURPOSE OF THE INVESTIGATIONS.

The investigations were planned with a view of ascertaining primarily the relation of two factors, handling and precooling, to the decay of these fruits in transit and on the market when shipped in a fresh or green state. The term "green" in this discussion is used to designate fruit shipped fresh, in contrast to fruit canned or evaporated. If a considerable proportion of the crop could be successfully shipped in this way during certain seasons, it would tend greatly to steady and stabilize the industry and permit its further profitable extension. The results would also indicate the important relationship of methods of handling to the decay of such fruits in transit and on the market, no matter where grown.

During the seasons of 1911 and 1913, the two seasons during which these investigations were carried on, the conditions were extremely unfavorable for green-fruit shipping, frequent rains interrupting both the sweet-cherry and prune picking during the harvesting seasons. The results obtained, however, particularly from the careful-handling experiments, are entirely consistent with the previous results of the department's fruit handling and transportation investigations. While the work in the Willamette Valley did not extend

over as many seasons as is usually considered desirable in order to warrant definite conclusions and recommendations, the marked and consistent results obtained, in spite of extremely unfavorable weather conditions, are considered of more than ordinary value and importance. The results of the experimental work with both cherries and prunes serve further to corroborate the results of similar work with oranges, lemons, apples, pears, red raspberries, peaches, and pine-apples, and to emphasize the great importance of the most careful handling in preparing fruit for shipment.¹

OUTLINE OF THE EXPERIMENTS.

Both careful-handling and precooling investigations were conducted with sweet cherries and prunes during the season of 1911. The work with prunes during the season of 1913 was confined largely to the precooling of carefully handled lots, there being no comparable commercially handled lots of fruit for purposes of comparison, as rainy weather during the harvesting season rather discouraged fresh-fruit shipments, especially as the prices prevailing for evaporated or dried fruits were eminently satisfactory. On account of the impracticability of securing a consignment of any definite number of cars to any one market, actual shipping experiments had to be omitted during both years, and all experimental series were held in an iced car at Salem.

Everything possible was done to make the conditions in the refrigerator holding car comparable with the conditions existing in fully loaded cars in transit, but even with the most careful attention to the details of icing, of placing the fruit in racks at different heights from the floor to obtain various desired temperature conditions, and of other precautionary measures, the general temperature conditions in the holding car were probably more favorable to the fruit than they would have been under actual transit conditions. The non-precooled fruit cooled more quickly and the ripening processes and the development of mold fungi proceeded more slowly in the holding car than would have been the case if shipped in a fully loaded and iced refrigerator car. In view of these facts, the results obtained may be considered even more impressive, as it is reasonable to expect that differences between carefully handled and ordinarily handled fruit would be even greater under actual shipping conditions than those found in a stationary, partially filled, iced refrigerator car. The differences between precooled and nonprecooled

¹ Powell, G. H., and others. The decay of oranges while in transit from California. U. S. Dept. Agr., Bur. Plant Indus. Bul. 123, 79 p., 26 fig., 9 pl. (2 col.), 1908.

Stubenrauch, A. V., Ramsey, H. J., Tenny, L. S., and others. Factors governing the successful shipment of oranges from Florida. U. S. Dept. Agr. Bul. 63, 50 p., 26 fig., 15 pl., 1914.

Ramsey, H. J. Factors governing the successful shipment of red raspberries from the Puyallup Valley. U. S. Dept. Agr. Bul. 274, 37 p., 26 fig., 1915.

fruit certainly would be much greater under transit conditions than under the holding conditions described.

The cherries were held in the iced car for lengths of time approximating transit periods of 5, 10, and 15 days. Inspections were made at withdrawal, and again 2 and 4 days after withdrawal. The prunes were inspected after holding periods of 10, 15, and 20 days in a refrigerator car, and again 2, 4, and 6 days after withdrawal from the car.

CAUSES OF DECAY IN TRANSIT.

The losses caused by the decay of cherries and prunes in transit are due primarily to fungi gaining entrance through mechanical abrasions in the skin or other injuries and to brown-rot (*Sclerotinia fructigena*). In general, these may be divided into two groups: (1) The fungi which have not the power to penetrate the sound, unbroken skin of fruits, but depend entirely upon injuries or mechanical abrasions for entrance, and (2) the fungi which can attack and cause the decay of sound fruit, either on or off the tree. An instance of the latter is the brown-rot, which, during certain seasons, is very serious on stone fruits. The investigations during the seasons of 1911 and 1913 show that this fungus is the cause of serious losses in transit, both in cherries and prunes, and the prevention of such losses must necessarily be dependent upon proper and effective orchard sanitation and spraying practices.¹

The most common fungi gaining entrance through injuries and mechanical abrasions and causing serious losses in transit are the common gray mold (*Botrytis*) and blue mold (*Penicillium*). These two fungi are responsible for most of the losses, aside from those occasioned by brown-rot. They gain entrance either through mechanical abrasions or injuries made in picking, hauling, and packing, or through cracks and splitting in both cherries and prunes by reason of rainy weather just prior to or at harvesting time. These fungi are dependent upon injuries or breakages of the skin for entrance; hence, the remedy obviously lies in the handling of the fruit in such a way as to prevent bruising and injury and in the careful grading out of all cracked or split fruit at the time of packing.

CHERRY INVESTIGATIONS.

DESCRIPTION OF COMMERCIAL HANDLING METHODS.

As previously stated, the greater part of the cherry crop in this section is either canned, put up in barrels for maraschino purposes, or evaporated. Under ordinary conditions of handling, either for the

¹ Jackson, H. S. Diseases of drupaceous fruits.—Brown-rot of stone fruits. In Oreg. Agr. Exp. Sta., Bien. Crop Pest and Hort. Rpt., 1911-12, p. 248-250, fig. 3, 1912.

Bailey, F. D. Experimental spraying of prunes for control of brown-rot. In Oreg. Agr. Exp. Sta., 2d Bien. Crop Pest and Hort. Rpt., 1913-14, p. 241-244, 1915.

purposes enumerated or for fresh-fruit shipment, the cherries are picked into pails, or buckets, of various sizes and types. Five-pound pails and 10-pound buckets are the most common, some of the buckets now in use having canvas bottoms as an added protection to the fruit, both in picking into the pail and in emptying into the field box. The pickers are paid by the pound, and as most of the fruit goes to the canneries or is intended for maraschino firms, not any too much care is exercised in picking. The cherries are grasped by the pedicel, and in the course of picking considerable bruising results from the holding of several in the hand before placing them in the pail or box. The fruit is emptied from the picking pail into boxes holding approximately 50 pounds and in these is hauled to the cannery or packing house.

Fruit for shipment is ordinarily packed in the standard 10-pound cherry box with two compartments, each about 10 inches square and $2\frac{1}{2}$ inches deep. The box is first faced with two layers of cherries diagrammatically arranged according to the size of the fruit, the rest being simply filled in. In putting in the facing layers, the fruit must be packed very firmly and tightly. The facing operation often results in breaking the internal structure of the cherry and in much bruising, which later develops into serious decay. Up to the present time this territory has seldom had enough fresh cherries in good condition to warrant car-lot shipments, and for that reason most of the fruit is sent out in small lots to the near-by cities, to points in California, and to markets occasionally as far east as Denver. The pony refrigerator is not used to any extent, and nearly all the fruit is shipped without refrigeration.

CAREFUL-HANDLING EXPERIMENTS.

The careful-handling experiments with cherries were carried on during the season of 1911. Table I and figure 1 give the average results of these experiments for that season. A study of these data emphasizes very strongly the relationship of handling to the condition of cherries in transit and on the market.

The decay figures, as given in Table I, are a total of all decay, exclusive of brown-rot, although it was quite impracticable in all cases to separate with absolute accuracy this trouble from other forms of decay. At the end of five days in the iced car, the carefully handled fruit showed only 0.5 per cent of decay, while the comparable commercially handled fruit showed 2.8 per cent of decay, practically six times the decay found in the comparable carefully handled lots. The results are equally striking at the end of transit periods of 10 and 15 days, the carefully handled fruit having 1.5 per cent of decay at the end of 10 days and 4.3 per cent of decay at the end of 15 days,

respectively, as against 12.3 per cent of decay and 16 per cent of decay for the same periods in the commercially handled fruit. At the end of a 10-day transit period, which is approximately equal in time to shipment to Chicago, the commercially handled fruit showed over eight times as much decay as developed in the same fruit when carefully handled.

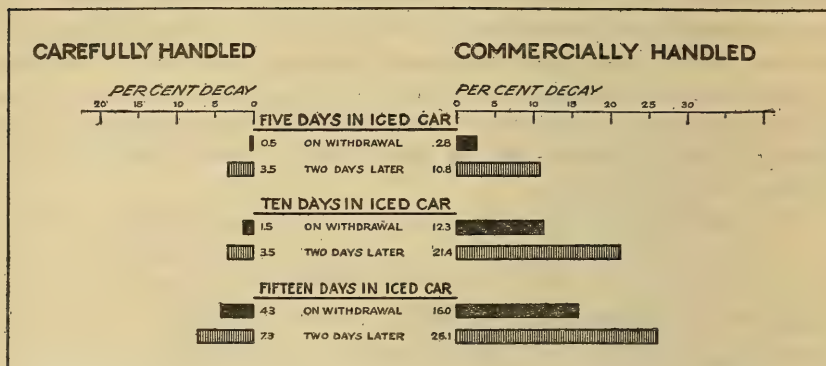


FIG. 1.—Diagram illustrating the percentages of decay in carefully and commercially handled cherries, Salem, Oreg., 1911.

TABLE I.—Decay in carefully and commercially handled cherries, Willamette Valley, season of 1911.

Time in iced car.	Time and manner of handling and extent of decay (per cent).			
	On withdrawal.		Two days after withdrawal.	
	Careful.	Commercial.	Careful.	Commercial.
5 days.....	0.5	2.8	3.5	10.8
10 days.....	1.5	12.3	3.5	21.4
15 days.....	4.3	16.0	7.3	26.1

MARKET HOLDING TESTS.

It is not only essential that the fruit be delivered on the market in sound condition, but it is also of the greatest importance that it remain in good, sound condition for a reasonable period, for distribution to the consumers. Fruit that does not keep well after arrival or which shows considerable spoilage while in the wholesalers' or retailers' hands soon gets a reputation for poor keeping quality and is seriously discounted, even though it arrives in practically sound condition.

The differences, as indicated in Table I, between commercially and carefully handled fruit two days after withdrawal are, if anything, more striking than the results on arrival. The inspection of the care-

fully handled lots of fruit two days after withdrawal from the car and after holding under ordinary market conditions for 5, 10, and 15 day transit periods showed, respectively, 3.5, 3.5, and 7.3 per cent of decay. The comparable commercially handled fruit two days after withdrawal showed 10.8, 21.4, and 26.1 per cent of decay, respectively, after corresponding transit periods. The commercially handled fruit in the car for 10 days and held for two days under open-market conditions developed more than six times the decay found in the same fruit when carefully handled.

RELATION OF HANDLING AND CULTURAL PRACTICES TO DECAY.

The striking results obtained in the careful-handling experiments indicate that if proper care is exercised in handling, picking, hauling, and packing, the shipment of cherries in a fresh state as far as Chicago would be entirely practicable. With the present commercial-handling methods, however, the long-distance shipment of fresh sweet cherries is not likely to prove uniformly profitable or successful, not only on account of the decay occurring in transit but because of the great amount of decay that develops during only a 2-day holding period on the market. Even though cherries can be delivered in fairly sound condition through careful attention to the details of handling, precooling, and refrigeration in transit, the problem of the successful shipment of cherries in a fresh state from the Willamette Valley and sections with similar climatic conditions involves more than harvesting and shipping practices alone.

The humid climate and frequent rains during the harvesting season render fruits like cherries and prunes extremely subject to serious attack by brown-rot. Rains during the harvesting season cause considerable splitting, especially with certain varieties of cherries, and while the badly cracked cherries are usually all graded out, it is impossible to grade out all the fruit affected with brown-rot. This type of decay in a package spreads very rapidly to adjoining fruits by contact, and in this respect is unlike the common molds, such as *Penicillium* and *Botrytis*, which depend largely on injuries for entrance. During some seasons brown-rot is not very serious. Nevertheless, if the growers of cherries make a business of fresh-fruit shipping, success will depend not only upon the exercise of proper care in handling but also upon correct cultural and spraying practices.

WHAT CONSTITUTES CAREFUL HANDLING.

The question of what constitutes the careful handling of cherries may, perhaps, be partially answered by describing the methods used in picking and packing the experimental lots. The cherries, as is customary, were picked by grasping the stems and exercising care not

to hold too many in the hand or to crush or bruise them in any way while picking and before placing in the pail or bucket. A 5-pound pail was used in the experimental work, the bottom being lined with paper. The cherries were all placed in the pail carefully and not dropped in or thrown in, as is often the commercial practice. In emptying into the orchard box great care was also exercised to prevent bruising and injury. The pail was first lowered to near the bottom of the box, the fruit in emptying being held back by the hand so as to allow it to roll gently into the box. The "lugs," or orchard boxes, were lined with paper, and not more than 25 or at the most 30 pounds of fruit were ever placed in any one box. The boxes were set in the shade until loaded on spring wagons for hauling to the packing house. In hauling to the packing house the fruit was protected by canvas or dusters from the dust and sun.

The carefully handled lots were picked and packed by representatives of the Bureau of Plant Industry, the ordinary 10-pound box being used for packing. The fruit was packed directly from the lug box, and all stemless, cracked, bruised, or injured fruit was graded out, special effort being made to pack the facing layers firmly and the rest of the box without bruising any of the fruit or breaking down its internal structure. The results of this extra care and the relation of handling methods are clearly brought out in the table and charts previously referred to. These favorable results were obtained by using practically all the ordinary equipment common in commercial practice. No doubt better picking receptacles than the paper-lined 5-pound pails, for instance, can be found. However, given any picking receptacle or pail, the care exercised in picking the fruit, in placing it in the pail, and in transferring it to the orchard box determines the amount of injury in picking and the resultant decay. The amount of injury done in picking and hauling is strikingly shown in the inspection of several lots of commercially handled fruit in the packing house before packing. In some instances 75 per cent of all the fruit examined showed evidences of serious bruising.

While these investigations indicate that cherries can be successfully shipped in the 10-pound box if sufficient care is exercised in all the operations of handling, they also prove that cherries under certain humid climatic conditions are more susceptible to injury in handling than in the more arid sections. Various growers in the Willamette Valley and in other humid sections of the Pacific Northwest have made trial shipments of cherries in berry crates, with uniformly good results. Much of the decay in transit results directly from bruises and injuries incurred in packing and facing the fruit in these 10 and 20 pound boxes. Nearly all of this bruising can be eliminated and the cost of packing very materially reduced where

berry crates or similar types of carton packages are used. A more extended trial of such packages for the shipment of cherries from sections like the Willamette Valley would seem to be desirable. The 10-pound cherry box when well packed is a very attractive package and is intimately associated with western cherries in the minds of the eastern and middle-western fruit trade. While the appearance of package and product counts for a great deal on the market, soundness is of first consideration. Even though cherries in berry crates or similar packages may not command the price that they would in the 10-pound box, it is a question whether this would not be offset by the decreased cost of packing and the better condition of the fruit. These factors can hardly be satisfactorily determined without commercial tests.

PRECOOLING EXPERIMENTS.

The precooling plant constructed by the Salem Fruit Union was utilized for the precooling experiments. In these experiments both carefully and commercially handled fruit was used in each series,

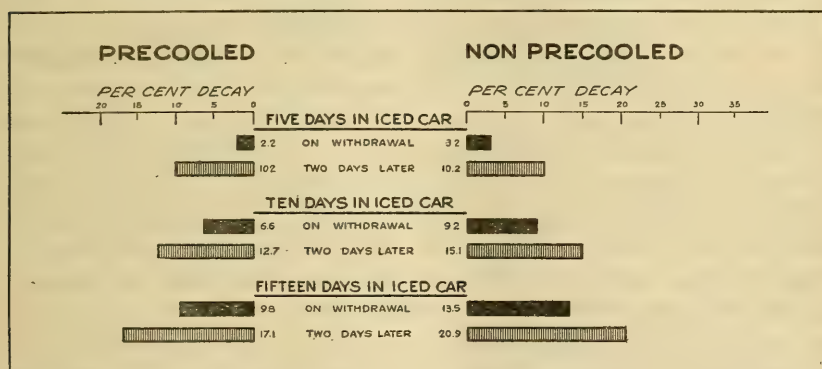


FIG. 2.—Diagram illustrating the percentages of decay in precooled and nonprecooled cherries commercially handled, Salem, Oreg., 1911.

one half of each lot being precooled and the other half placed in the refrigerator car without precooling. The data given in Table II, which are illustrated graphically in figure 2, show the relation of precooling to decay and market condition, wherein only the results of the commercially handled fruit are given, the small amount of decay in the carefully handled fruit being practically the same in both the precooled and nonprecooled lots.

While there are consistent differences in favor of the precooled fruit, these are not nearly so striking as the differences between the carefully and commercially handled lots, and although they bring out to some extent the value of precooling, they emphasize most strongly the importance of careful handling. The fruit in the precooling experiments was usually cooled to a temperature of 40° F.

or lower. The transfer to the iced car was made without exposing the cooled fruit to contact with the warmer air outside.

TABLE II.—*Decay in precooled and nonprecooled cherries, commercially handled, Willamette Valley, season of 1911.*

Time in iced car.	Time and treatment and extent of decay (per cent).			
	On withdrawal.		Two days after withdrawal.	
	Pre-cooled.	Nonpre-cooled.	Pre-cooled.	Nonpre-cooled.
5 days.....	2.2	3.2	10.2	10.2
10 days.....	6.6	9.2	12.7	15.1
15 days.....	9.8	13.5	17.1	20.9

The decay on withdrawal at the end of a 10-day transit period is fairly representative of the general results of the precooling tests. The precooled, commercially handled fruit at the end of 10 days showed 6.6 per cent of decay, while the nonprecooled fruit showed 9.2 per cent of decay, and after holding on the market for two days the precooled fruit developed 12.7 per cent of decay and the nonprecooled 15.1 per cent of decay. A comparison of the differences between the precooled and nonprecooled lots in Table II with the differences between the carefully and commercially handled fruit in Table I will serve to emphasize strongly the fundamental importance of careful handling. In interpreting the precooling results, however, one should bear in mind the fact that the nonprecooled lots were placed in a partially filled, well-iced refrigerator car and that these crates cooled more quickly than they would in a full carload in transit. Greater differences in decay and condition between precooled and nonprecooled fruit would naturally be expected under actual shipping conditions. One difference not brought out in the tables or charts is that of appearance, the precooled fruit being uniformly and consistently much brighter and fresher than the nonprecooled.

EFFECT OF DELAY IN LOADING AND COOLING.

Table III and figure 3 illustrate very strikingly the importance of handling the fruit from the tree to the refrigerator car or of delivering it to the carrier or transportation company with the least delay possible.

Table III gives the decay in comparable lots of fruit, one half of which had been picked, packed, and shipped immediately, the other half being delayed two days before placing in the refrigerator car. At the end of a 5-day transit period the immediate lots showed 3.2

per cent of decay, as compared with 5.2 per cent in the same fruit delayed two days before loading. The results in the lots held for 10 days are equally striking, there being 13.5 per cent of decay in the immediate and 25.4 per cent in the delayed shipments on withdrawal from the car, with 19.7 per cent in the immediate and 40.2 per cent in the delayed shipments after a market holding period of 2 days. On arrival, the delayed fruit invariably showed about twice the decay found in the fruit immediately packed and loaded.

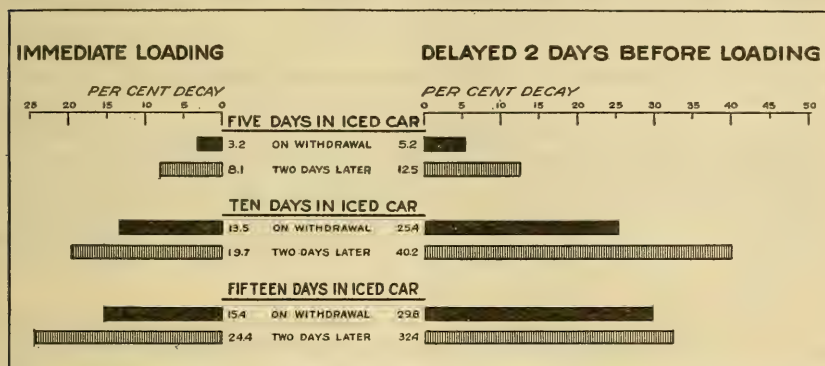


FIG. 3.—Diagram illustrating the percentages of decay in commercially handled nonprecooled cherries loaded immediately and those delayed two days in the warehouse before loading, Salem, Oreg., 1911.

TABLE III.—Decay in commercially handled nonprecooled cherries immediately loaded and in those delayed two days in the warehouse before loading, Willamette Valley, season of 1911.¹

Time in iced car.	Time factors and extent of decay (per cent).			
	On withdrawal.		Two days after withdrawal.	
	Immediate.	Delayed.	Immediate.	Delayed.
5 days.....	3.2	5.2	8.1	12.5
10 days.....	13.5	25.4	19.7	40.2
15 days.....	15.4	29.8	24.4	32.4

¹ Slight inconsistencies and apparent discrepancies occur in this table and in some others. These, however, are easily accounted for when it is taken into consideration that it was impossible to use the same lots of fruit for more than one inspection. While the aggregate of fruit used in these inspections was large, the quantity of fruit in each experiment was necessarily limited, especially the fruit used for each inspection. The rather high development of decay in some portion of a crate, either on account of accidental injuries in handling or of decay resulting from brown-rot, is primarily responsible for most of these apparent discrepancies.

The results shown in this table serve to emphasize the desirability and the necessity of getting the fruit as quickly as possible into cooler temperatures or into the refrigerator car, or, where it is shipped without refrigeration, of forwarding it to the carrier or transportation company with the least possible delay. Holding the fruit for

any considerable time either in the field or warehouse before shipping only gives added opportunity for decay to start in bruises and injuries, while the ripening processes also proceed more rapidly under these high temperatures and result in quicker decay and deterioration. Leaving the fruit in the field for several hours, especially during hot weather, will seriously affect the shipping quality of such tender and perishable fruits as cherries. In the handling of cherries for shipment it is essential that the fruit be hauled in promptly after picking, that it be packed as soon as received at the packing house, and immediately cooled, loaded, and shipped.

SUMMARY OF THE CHERRY INVESTIGATIONS.

When the large acreage of recently planted sweet cherries in the Willamette Valley comes into bearing, the production will be greatly increased. If, therefore, cherries can be successfully shipped and disposed of in a fresh state, there would be provided a wider and possibly a more profitable outlet for a considerable proportion of the cherry crop.

The shipment of cherries in a fresh state for long distances has been more or less unsuccessful, owing to the development of a large amount of decay and deterioration in transit and on the market. This decay is due to fungi which gain entrance to and attack the fruit through mechanical abrasions made in handling, to splitting due to rainy weather at harvesting time, or to brown-rot, which infects the fruit in the orchard.

The results of these investigations demonstrate conclusively that the losses due to mold fungi gaining entrance through mechanical abrasions and injuries can be largely prevented by the exercise of proper care in picking, hauling, and packing, and in the careful grading out of all injured, stemless, and cracked fruit.

Precaution should be taken not to bruise the fruit in the hand when picking, when transferring it to the picking pail or bucket, or when emptying it from the picking receptacle into the field box.

During the time the fruit is held in the orchard after picking, it should be kept in the shade. The wagons for hauling should be provided with good springs and the load covered with canvas, in order to protect the fruit from the sun and dirt.

At the time of packing, the fruit should be carefully graded, so as to eliminate all stemless and cracked or split fruit. All cracked and stemless fruits included in the packing boxes are almost certain to decay, either from mold fungi or brown-rot.

If the fruit is packed in the ordinary 10-pound boxes, the greatest care must be exercised in putting in facing layers to prevent the bruising, injury, or breaking down of the internal structure of the fruit.

It is evident that cherries grown in humid sections subject to considerable rainy weather at harvest time are more susceptible to injury than similar varieties grown in the more arid sections, and they therefore require all the more careful handling. In view of this fact it would seem advisable where practicable to make more extended trials of shipping in berry crates, in this way obviating the necessity of tight packing.

Whether the cherries are shipped in carload lots under refrigeration or in smaller lots by express, immediate loading is essential.

Precooling or the prompt cooling of cherries before shipment is of material assistance in minimizing decay in transit. Precooling, however, is hardly justified unless the fruit is carefully and properly handled, and it should never be depended on to overcome the bad effects of rough or careless handling. It is essential that the fruit be cooled as quickly as possible after picking, that the precooling be thoroughly done, and that the fruit be transferred to the refrigerator car without exposure to the warmer outside temperatures.

PRUNE INVESTIGATIONS.

EXTENT AND STATUS OF THE INDUSTRY.

Prune growing is the leading horticultural industry of those portions of Polk and Marion Counties adjacent to Salem, as well as of several other counties in the Willamette Valley, Oreg. The Italian prune is the variety most widely planted and was used exclusively in these handling and precooling investigations. As almost the entire product of the section in the vicinity of Salem and in the Willamette Valley generally is evaporated, all cultural and handling operations have been developed with this end in view.

While the main dependence must be placed on marketing the product in an evaporated state, during most seasons it would be greatly to the growers' advantage if a portion of the fresh crop could be profitably shipped. The practicability of and success with fresh-prune shipments from this and other sections depend primarily on whether the product can be delivered in sound and good merchantable condition. During the seasons of 1910 and 1911 several carloads of fresh prunes were shipped to Chicago and other eastern markets under refrigeration, but with rather unsatisfactory results, due mainly to the fact that most of the shipments arrived in a badly decayed condition. Further shipments were planned for the season of 1913, but unfavorable weather conditions immediately preceding the harvesting season, along with attractive prices offered for the dried product, caused the growers to abandon all fresh-fruit shipping plans.

COMMERCIAL HANDLING METHODS.

The methods of harvesting prunes for fresh-fruit shipment are necessarily very different from those employed where the product is to be evaporated. In the latter case the prunes are allowed to fall on the ground or the trees are shaken periodically by pickers who go through the orchard with poles, especially for this purpose. As a rule, a great many pickings are made during the season. The product is afterwards picked up from the ground and hauled to the evaporators for grading and processing. The operations for harvesting prunes for shipment in a fresh state are very similar to those described for cherries. In picking, the prunes are grasped by the pedicel and placed in buckets or pails of various makes and sizes. From these they are poured into lug boxes, usually slatted and holding from 30 to 35 pounds. Sometimes the packing is done at the orchard or on the farm, but more often the prunes are hauled to a central packing house at the nearest shipping point. In the packing house the prunes are poured out on a sorting and packing table, the packers doing both the grading and packing. The package used is a 4-basket crate holding approximately 25 pounds of fruit. The sizes are designated as 4 by 5, 5 by 5, 5 by 6, and 6 by 6, the majority usually running about 5 by 5 and 5 by 6, and are based on the number of prunes in a row each way in the basket. One thousand crates constitute the usual standard carload of prunes, although the load may vary somewhat one way or the other.¹

PURPOSE AND OUTLINE OF INVESTIGATIONS.

As previously indicated, fresh-prune shipments have not yielded uniformly satisfactory returns, largely on account of the poor condition in which the prunes arrived on the market. These investigations, therefore, were inaugurated with a view to determining whether prunes grown in the Willamette Valley and in sections having similar climatic conditions can be handled with sufficient care to deliver them on the market in good, sound condition. During the season of 1911 quite a number of commercial car-lot shipments of fresh prunes were made, and the investigations that season were planned primarily to determine the relationship of handling methods, of delayed cooling and shipping, and of quick cooling or precooling to the decay and deterioration of fresh prunes in transit and on the market.

It was impracticable to make any experimental shipments to eastern markets, on account of the impossibility of securing a sufficient number of cars for one market, and the experimental lots were

¹ Lewis, C. I., Brown, F. R., and Bradford, F. C. A prune survey of Oregon. *In* *Oreg. Agr. Exp. Sta., Bien. Crop Pest and Hort. Rpt., 1911-12*, p. 8-30, 8 fig., 1913.

therefore held in an iced car at Salem under conditions approximating transit conditions as nearly as possible. During the season of 1913, although arrangements had been made for several car-lot shipments of fresh prunes to one market, the weather and other conditions were such as to make necessary the abandonment of these arrangements. During that season, therefore, no comparison of carefully and commercially handled fruit was possible, and the experimental work had to be confined largely to precooling tests with carefully handled fruit, maturity tests, and a comparison of fruit from different sections and soils. While the weather conditions during the two seasons mentioned were not the most favorable for fresh-fruit shipments, they were such as occur quite frequently during a series of years, and if prunes can not be shipped more or less successfully during such seasons entire dependence must be placed on the evaporated or dried products, and everything should be done with a view to growing fruit especially for this purpose and to curing a product of the very highest market quality.

RELATION OF HANDLING TO DECAY IN TRANSIT.

During the season of 1911 a number of experimental tests were made of carefully and commercially handled fruit. The carefully handled lots were picked and packed by representatives of the Bureau of Plant Industry, the fruit being secured from the same orchards and at the same time as that handled commercially. The lots are comparable in every way except in the care exercised in the picking, hauling, and packing.

TABLE IV.—*Decay in carefully and commercially handled prunes, Willamette Valley, season of 1911.*

Time in iced car.	Time and manner of handling and extent of decay (per cent).			
	On withdrawal.		Six days after withdrawal.	
	Careful.	Commercial.	Careful.	Commercial.
10 days.....	0.7	3.5	2.1	8.7
15 days.....	.4	7.1	3.7	16.6
20 days.....	2.7	6.8	6.9	23.3

The data presented in Table IV, which are illustrated graphically in figure 4, show the differences in decay between the carefully handled and commercially handled fruit. These lots were held in an iced car for 10, 15, and 20 days, and were inspected on withdrawal and again 2, 4, and 6 days afterwards, only the results of the in-

spectations on withdrawal and 6 days after withdrawal being shown. After 10 days in the iced car the carefully handled fruit had developed only 0.7 per cent of decay, as against 3.5 per cent for that commercially handled. Six days after withdrawal, the carefully handled fruit had developed 2.1 per cent of decay, as against 8.7 per cent for that commercially handled. After 15 days in the iced car the carefully handled fruit showed 0.4 per cent of decay and the commercially handled fruit 7.1 per cent of decay. Six days after withdrawal, this series had developed 3.7 per cent of decay in the carefully handled fruit, as against 16.6 per cent in the fruit handled in the ordinary commercial manner.

The commercially handled fruit had developed during a transit period of 10 days almost five times as much decay as the fruit handled

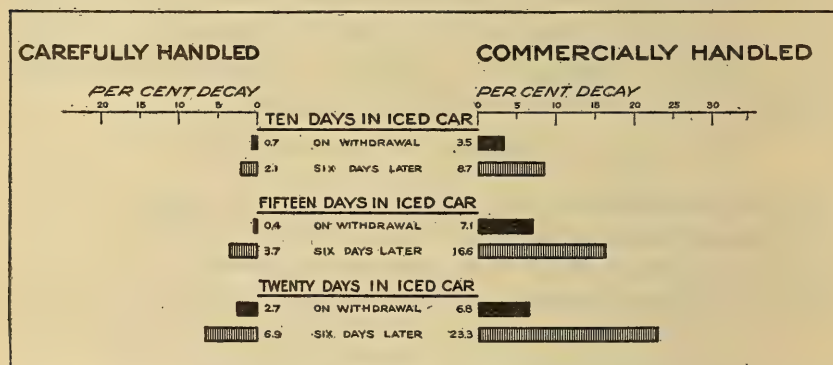


FIG. 4.—Diagram illustrating the percentages of decay in carefully and commercially handled prunes, Salem, Oreg., 1911.

carefully, and after holding for 6 days on the market the commercially handled fruit still showed four times as much decay as that carefully handled. The same relative differences hold true for the 15 and 20 day periods.

These figures illustrate strikingly the important relation of handling to the decay of prunes in transit and clearly bring out the need of great improvement in handling methods before prunes can be successfully and profitably shipped from this section in a green or fresh condition. While the decay developed in the commercially handled fruit on arrival is not proportionately large, it is sufficient to affect seriously the market value of the fruit, especially in view of the rather rapid development of decay under market holding conditions. It must also be borne in mind that all of these lots were held in an iced refrigerator car under very favorable conditions, the fruit cooling very much faster than it would in a full carload and generally being held under more favorable temperatures and conditions than would be the case under ordinary transit conditions.

IMPORTANCE OF CAREFUL HANDLING AND GRADING.

An average of all the tests made during the season of 1911 indicates the urgent necessity of improvement in field and packing-house handling. Every precaution should be exercised in picking, hauling, packing, and all harvesting operations to avoid bruising or mechanical injury of any kind. In picking, the fruit should be grasped by the stem and placed by hand in a bucket or picking receptacle and should be handled in such a way as to disturb the bloom as little as possible. What has been said regarding cherries will hold equally true for prunes. Every precaution should be taken to transfer the fruit from the bucket to the lug box without allowing the fruit to drop or roll violently any distance or to rub off any more bloom than is consistent with the handling that has to be given it. Oftentimes it is the practice in the Willamette Valley to pick only the lower branches of the trees, leaving the fruit in the upper branches for drying or evaporation. In such cases it is sometimes possible to pick, at least for a portion of the time, directly into the lug box. Even if this extra care takes a little more time it is entirely practicable, and in minimizing the injury and consequent decay the slight added cost of handling is more than compensated for.

The fruit should be kept in the shade while in the orchard after picking and should be hauled to the packing house on wagons equipped with good springs. The load should also be covered with canvas or some other covering to protect it from the sun and dust. In packing, much bruising and injury can be avoided by sorting and packing directly from the lug box instead of pouring the fruit out in bins or on tables, as is oftentimes the practice. The preservation of the bloom is a very important factor in the marketing of fresh prunes. When the prunes are poured into bins or on tables, much of the bloom is rubbed off that could be preserved if the fruit were packed and sorted directly from the lug box.

It is certain that if fresh-prune shipping is to become a profitable and established phase of the marketing of this crop in the Willamette Valley, much greater care must be devoted to the handling and grading of the fruit. Not only should care be exercised to avoid mechanical injuries of every kind, but closer grading is absolutely necessary, in order that the fruit may at least leave the packing house in good, sound condition. Usually insufficient care is exercised in grading and in sorting out injured, soft, and cull fruit. This failure to grade and cull closely is partially responsible for the fact that occasionally the fruit shows some decay and deterioration prior to shipment. Brown-rot is also a considerable factor, and the decay data for both seasons include that caused by brown-rot, as it was quite impossible to separate this from other forms at all times.

The relation, however, of this form of decay to transportation conditions and the practicability of fresh-fruit shipping is well illustrated in the data giving the results of the work in 1913.

EFFECT OF DELAYED SHIPMENT ON KEEPING QUALITY.

During the season of 1911 half of all the experimental lots of prunes were held for two days in the warehouse before being placed in the precooling room or in the refrigerator car, in order to determine the effect of delayed cooling and shipping. While it is generally recognized that delay in the cooling or shipping of any perishable fruit product is inadvisable from the standpoint of decay and condition, in certain localities a delay of two or three days is of frequent occurrence. This is especially true where two to four days are

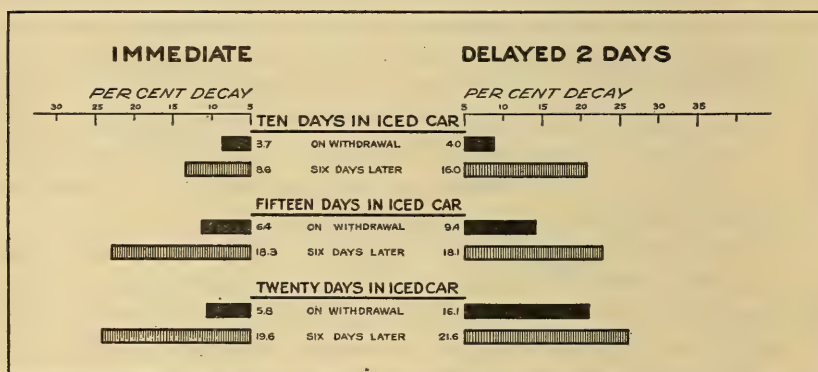


FIG. 5.—Diagram illustrating the percentages of decay in commercially handled nonpre-cooled prunes immediately loaded and those delayed two days in the warehouse before loading, Salem, Oreg., 1911.

required to assemble a full carload, the fruit meantime being held in sheds or packing houses.

Table V and figure 5 give a comparison of decay in commercially handled fruit loaded immediately and delayed two days in the packing house before loading. After a transit period of 10 days the fruit immediately loaded had developed 3.7 per cent of decay and the delayed fruit 4 per cent. After a 15-day holding period the immediate and delayed lots had developed 6.4 per cent and 9.4 per cent of decay, respectively, and the immediately loaded fruit in transit 10 days and held 6 days under ordinary market conditions showed 8.6 per cent of decay, as against 16 per cent for the fruit delayed two days prior to shipment. While these differences are not as striking, or perhaps as consistent, as those found between carefully and commercially handled fruit, they nevertheless indicate the necessity of prompt shipment after picking and packing. The seriousness of delay before loading and shipping will also depend largely upon the temperature conditions at harvesting time. If the temperatures are abnormally high, a delay of a few hours in the packing

house may be as serious as two or more days during periods of rather low temperatures.

TABLE V.—Decay in commercially handled nonprecooled prunes immediately loaded and in those delayed two days before loading, Willamette Valley, season of 1911.

Time in iced car.	Time factors and extent of decay (per cent).			
	On withdrawal.		Six days after withdrawal.	
	Immediate.	Delayed.	Immediate.	Delayed.
10 days.....	3.7	4.0	8.6	16.0
15 days.....	6.4	9.4	18.3	18.1
20 days.....	5.8	16.1	19.6	21.6

Table VI and figure 6 present a comparison of immediate and delayed shipments of carefully handled prunes during the seasons of 1911 and 1913. The results in the carefully handled lots during

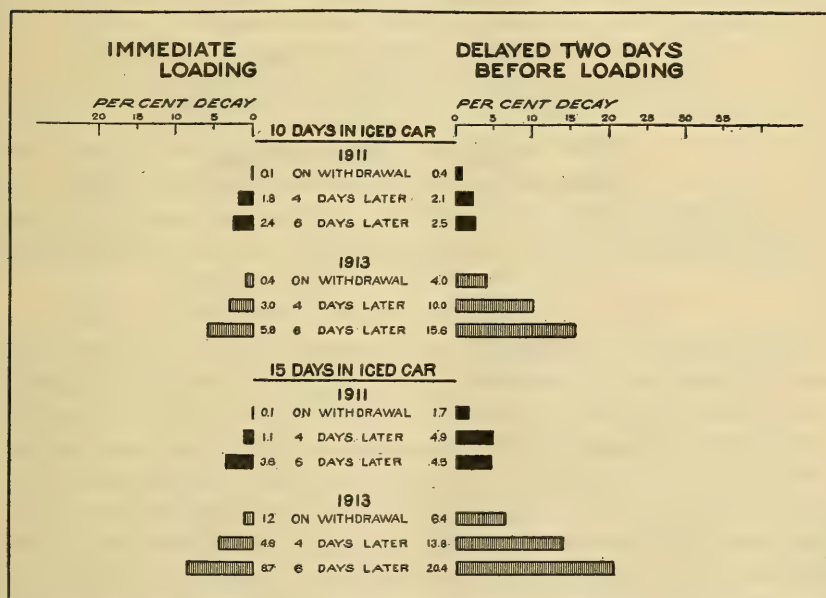


FIG. 6.—Diagram illustrating the percentages of decay in carefully handled nonprecooled prunes immediately loaded and those delayed two days in the warehouse before loading, Salem, Oreg., 1911 and 1913.

1911 are entirely consistent with the data given in Table V for the commercially handled prunes, the delayed lots uniformly showing more decay than those in the immediately loaded or shipped lots. It will also be noted that the figures for 1913 show considerably more decay than those for 1911, due mainly to the fact that more brown-rot developed during the season of 1913.

TABLE VI.—*Decay in carefully handled nonprecooled prunes immediately loaded and in those delayed two days in the warehouse before loading, Wiltamette Valley, seasons of 1911 and 1913.*

Time of inspection.	Time factors and extent of decay (per cent).							
	Season of 1911.				Season of 1913.			
	Immediate shipment.		Delayed shipment.		Immediate shipment.		Delayed shipment.	
	10-day withdrawal.	15-day withdrawal.	10-day withdrawal.	15-day withdrawal.	10-day withdrawal.	15-day withdrawal.	10-day withdrawal.	15-day withdrawal.
On withdrawal.....	0.1	0.1	0.4	1.7	0.4	1.2	4.0	6.4
4 days after withdrawal.....	1.8	1.1	2.1	4.9	3.0	4.6	10.0	13.8
6 days after withdrawal.....	2.4	3.6	2.5	4.5	5.8	8.7	15.6	20.4

The data for 1913 emphasize even more strongly than the 1911 data the necessity for prompt shipment. After a transit period of 10 days the immediately loaded fruit showed on arrival 0.4 of 1 per cent of decay and 5.8 per cent after a holding period of six days, as compared with 4 per cent of decay on arrival and 15.6 per cent at the end of a holding period of six days in the delayed fruit. The 15-day withdrawals are equally consistent and show, of course, in the aggregate, more decay than the figures just given for the 10-day transit period. Where brown-rot is an important factor, as it was during 1913, prompt cooling and shipping is a prime necessity, and any considerable delay before cooling or shipping means the almost certain arrival of the fruit on the market in a very badly decayed condition.

EFFECT OF PRECOOLING ON CARRYING QUALITY.

The precooling experiments, as previously mentioned with cherries, were carried on in connection with a small precooling plant of 1-carload capacity built by the Salem Fruit Union under the supervision of the Bureau of Plant Industry. This plant was the first of its kind to be erected, and in it the principle of passing air directly through the mixture of ice and salt was adopted. The tank containing the refrigerating mixture is filled with crushed ice and salt, the air being passed through the bottom of the tank, and as the ice melts a new supply continually drops from the upper part of the tank. In this way the tank can be operated through an entire run without refilling. The precooling room is fitted with a false floor and return ducts, and by means of a fan the cool air is forced below the floor and through holes or openings in the false floor into the room, to circulate between the fruit packages stacked therein. The air is drawn back through the ceiling ducts to the ice tank and again circulated, the same air being used throughout the process. This method was utilized in the precooling experiments

with cherries, prunes, and loganberries, and afforded excellent facilities for testing this type of plant, the practical phases of warehouse precooling, and the relation of quick cooling to the more perishable fruits grown in this section.

Table VII and figure 7 present a comparison of the decay in the precooled and nonprecooled prunes commercially handled during the season of 1911. While these figures show consistent differences in favor of precooling, these differences are by no means as striking as are those between fruit carefully and commercially handled. The favorable results obtained from precooling are probably sufficient to justify fully the necessary expenditure in case fresh-fruit shipping becomes an established practice with prunes and other small fruits in

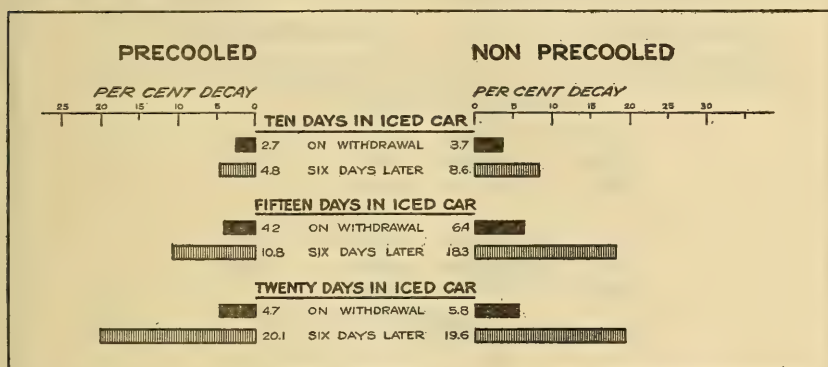


FIG. 7.—Diagram illustrating the percentages of decay in precooled and nonprecooled prunes commercially handled, Salem, Oreg., 1911.

the Willamette Valley. The figures as given do not do full justice to the precooled lots, because of the rapidity with which the nonprecooled fruit cooled after being placed in the partially filled refrigerator car. The nonprecooled fruit reached a temperature of 40° F. in a very few hours, whereas under ordinary transit conditions it would have required several days for most of the fruit to be reduced to a temperature at which the ice would hold it. Therefore, in interpreting the precooling data these factors should be taken into consideration. The precooled fruit showed considerably less decay, even under the conditions under which the fruit was handled and held in this experimental work, but it is reasonable to expect that the differences would have been very much greater in favor of precooling if full car-load shipments had been possible. In most cases the experimental lots used in these precooling experiments were placed with a full carload of fruit in the precooling room, and the work was therefore done in most cases on a commercial basis. Where the room was filled with one carload of fruit the cooling was accomplished in about six hours and required an average of about 2½ tons of ice for cooling.

TABLE VII.—*Decay in precooled and nonprecooled prunes, commercially handled, Willamette Valley, season of 1911.*

Time in iced car.	Time and treatment and extent of decay (per cent).			
	On withdrawal.		Six days after withdrawal.	
	Pre-cooled.	Nonpre-cooled.	Pre-cooled.	Nonpre-cooled.
10 days.....	2.7	3.7	4.8	8.6
15 days.....	4.2	6.4	10.8	18.3
20 days.....	4.7	5.8	20.1	19.6

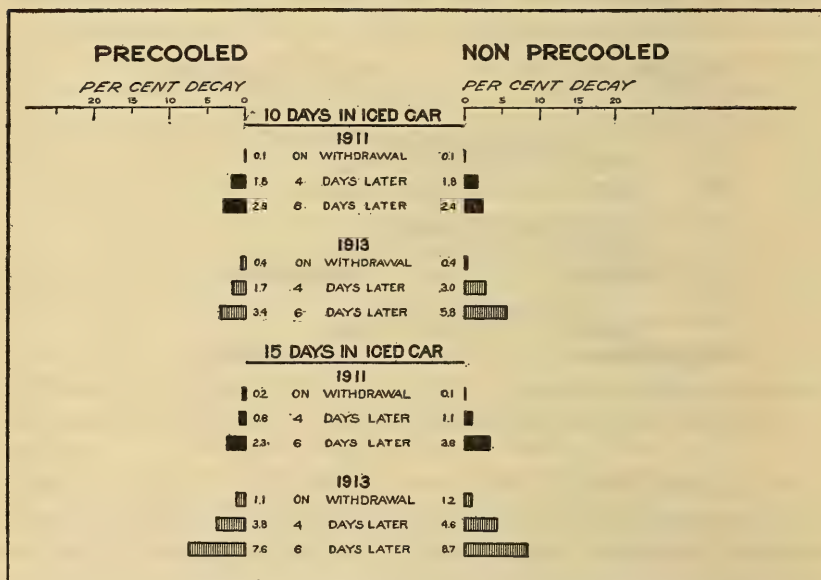


FIG. 8.—Diagram illustrating the percentages of decay in precooled and nonprecooled prunes carefully handled, Salem, Oreg., 1911 and 1913.

TABLE VIII.—*Decay in precooled and nonprecooled fresh prunes, carefully handled, Willamette Valley, seasons of 1911 and 1913.*

Time of inspection.	Time factors and extent of decay (per cent).							
	Season of 1911.				Season of 1913.			
	Precooled.		Nonprecooled.		Precooled.		Nonprecooled.	
	10-day withdrawal.	15-day withdrawal.	10-day withdrawal.	15-day withdrawal.	10-day withdrawal.	15-day withdrawal.	10-day withdrawal.	15-day withdrawal.
On withdrawal.....	0.1	0.2	0.1	0.1	0.4	1.1	0.4	1.2
4 days after withdrawal.....	1.8	.6	1.8	1.1	1.7	3.8	3.0	4.6
6 days after withdrawal.....	2.9	2.3	2.4	3.6	3.4	7.6	5.8	8.7

Table VIII and figure 8 present the results of the precooling tests with carefully handled fruit during the seasons of 1911 and 1913.

The results in the main are consistent with those given for the commercially handled lots during the season of 1911, the differences being proportionately about the same. It will be noted that in this case also the carefully handled fruit of 1913 shows somewhat more decay than during 1911, this, as previously mentioned, being due to the greater prevalence of brown-rot during the latter season. As in the case with cherries, the precooled fruit had a fresher and brighter appearance on removal from the car.

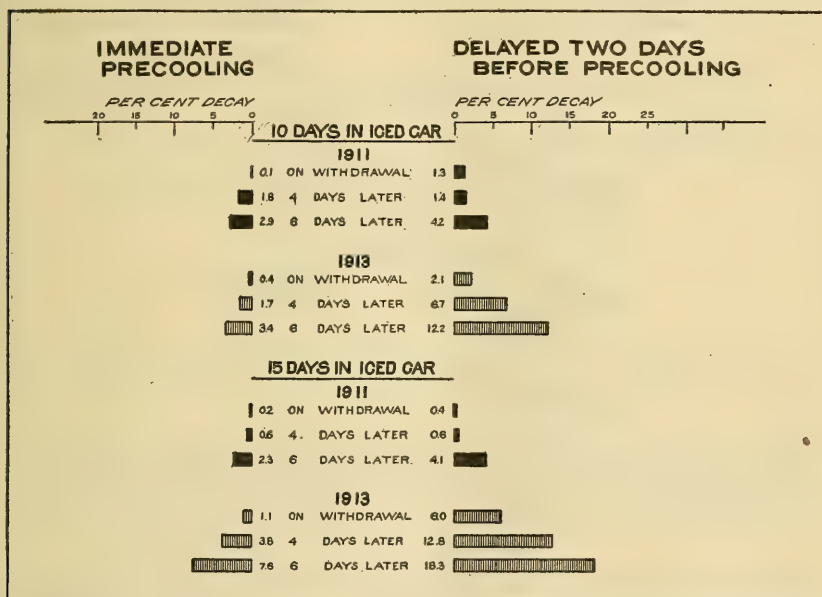


FIG. 9.—Diagram illustrating the percentages of decay in carefully handled prunes immediately precooled and those delayed two days before precooling, Salem, Oreg., 1911 and 1913.

DELAYED PRECOOLING.

To test the effect of delayed precooling as well as of delayed shipment, half of each lot or series in the precooling experiments was held two days before being placed in the precooling room. Table IX presents a comparison of the decay found in immediately cooled and in delayed fresh prunes, carefully handled, during the seasons of 1911 and 1913, and also a comparison of decay in fresh prunes similarly treated but commercially handled in the season of 1911. The results attending the carefully handled and commercially handled lots of fruit are graphically shown in figures 9 and 10, respectively.

A study of Table IX and its accompanying diagrams shows conclusively the necessity for promptness where precooling is practiced.

For instance, during 1913, in the carefully handled fruit in the 15-day withdrawal lot, the immediately precooled fruit showed 1.1 per cent of decay, as against 6 per cent in the fruit delayed prior to cooling. At the end of a 4-day holding period the fruit immediately precooled showed 3.8 per cent of decay, as against 12.8 per cent in the delayed precooled fruit. The data are equally consistent throughout and emphasize again the absolute necessity of handling the fruit from the tree to the car or the precooling plant with the utmost rapidity consistent with care in all operations.

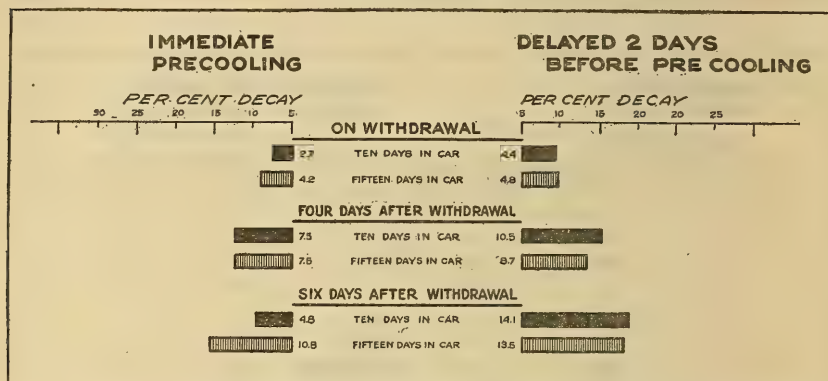


FIG. 10.—Diagram illustrating the percentages of decay in commercially handled prunes immediately precooled and those delayed two days before precooling, Salem, Oreg., 1911.

TABLE IX.—Decay in prunes immediately precooled and in those delayed two days in the warehouse before precooling, in carefully handled and commercially handled lots, Willamette Valley, seasons of 1911 and 1913.

Time of inspection.	Treatment, time factors, and extent of decay (per cent).									
	Carefully handled.								Commercially handled.	
	Season of 1911.				Season of 1913.				Season of 1911.	
	Immediately cooled.		Delayed 2 days before cooling.		Immediately cooled.		Delayed 2 days before cooling.		Immediately cooled.	Delayed 2 days before cooling.
	10-day withdrawal.	15-day withdrawal.	10-day withdrawal.	15-day withdrawal.	10-day withdrawal.	15-day withdrawal.	10-day withdrawal.	15-day withdrawal.	10-day withdrawal.	15-day withdrawal.
On withdrawal.....	0.1	0.2	1.3	0.4	0.4	1.1	2.1	6.0	2.7	4.2
4 days after withdrawal.....	1.8	.6	1.4	.6	1.7	3.8	6.7	12.8	7.5	7.5
6 days after withdrawal.....	2.9	2.3	4.2	4.1	3.4	7.6	12.2	18.3	4.8	10.8
									14.1	13.5

RELATION OF BROWN-ROT TO FRESH-PRUNE SHIPMENT.

During the seasons of both 1911 and 1913, and especially during the latter season, brown-rot was an important factor in determining the condition of prunes in transit and on the market. A great deal

of the decay occurring in the earlier lots during 1913 was due to brown-rot, as was a large portion of that in the later lots. Table X and figure 11 illustrate rather strikingly the relation of brown-rot to fresh-fruit shipment.

Table X shows the total decay in the four best series in the immediately precooled and nonprecooled fresh prunes, as compared with the percentages of total decay in the four poorest series under the same methods of handling. The four series in the best lots were from orchards that were practically free from brown-rot, the four poorer series being from orchards where brown-rot was very prevalent. The fruit from the disease-free orchards at the end of a 10-day transit period showed no decay on withdrawal, 0.3 of 1 per cent at the end

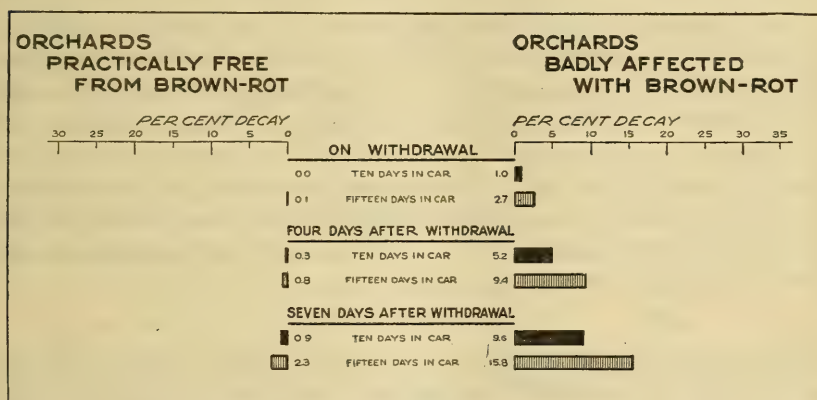


FIG. 11.—Diagram illustrating the percentages of decay in four series of prunes from orchards showing little or no brown-rot and comparable series from orchards badly affected with brown-rot, Salem, Oreg., 1913.

of 4 days, and 0.9 of 1 per cent at the end of a 7-day holding period, as against 1 per cent on withdrawal, 5.2 per cent after 4 days, and 9.6 per cent after a 7-day holding period in fruit from disease-infested orchards. It should also be kept in mind that this fruit was handled from all orchards with the greatest degree of care and that these differences were primarily due to the difference in brown-rot in the different lots. At the end of a 15-day transit period the better lots of fruit had developed only 0.1 of 1 per cent of decay on withdrawal, 0.8 of 1 per cent after a 4-day holding period, and 2.3 per cent after a 7-day holding period on the market, this as against 2.7 per cent of decay on withdrawal and 9.4 per cent and 15.8 per cent, respectively, for the poorer lots. The differences here are so striking as to indicate most clearly the need of correct cultural practices and thorough spraying in order to control the brown-rot, which during most seasons is a serious factor and one of the chief drawbacks to the successful shipment of prunes in a fresh condition.

TABLE X.—*Decay in four series of prune shipments from orchards showing little or no brown-rot and in comparable series from orchards badly affected with brown-rot, Willamette Valley, season of 1913.*

Time of inspection.	Brown-rot, time factors, and extent of decay (per cent).			
	Practically free from brown-rot.		Badly affected with brown-rot.	
	10-day with-drawal.	15-day with-drawal.	10-day with-drawal.	15-day with-drawal.
On withdrawal.....	0	0.1	1.0	2.7
4 days after withdrawal.....	.3	.8	5.2	9.4
7 days after withdrawal.....	.9	2.3	9.6	15.8

The possibility of marketing prunes in a fresh condition will depend, therefore, largely upon correct handling and cultural practices. The exercise of the necessary care in harvesting will prevent decay due to mechanical injuries made in handling. Proper cultural practices should secure the delivery to the packing house of prunes free from brown-rot infection. The successful solution of this problem will depend entirely upon the industry, that is, the efficiency shown in controlling the factors which to the greatest degree determine the condition of fresh prunes in transit.

MATURITY TESTS.

During the season of 1913 an effort was made to determine the proper stage of maturity at which prunes should be picked for fresh-fruit shipment. The excessive development of brown-rot in the experimental lots, especially during the early part of the season, tended to nullify any results that might have been obtained. Three picks were made one week apart, the first pick about three weeks before the fruit is normally harvested for evaporation or drying. It was believed by many people that the fruit would grow considerably between the first and last picks, but the data accumulated along this line indicate that there was no considerable increase in size between the first and third picking, except in one instance. If proper allowance is made for the prevalence of brown-rot during the early part of the season, the time of picking did not seem to have any noticeable effect on the keeping quality of the prunes. There was, however, a striking difference in the condition of the prunes at the final inspections of the early and late picks, the former showing no natural deterioration whatever, while the latter developed considerable.

The most striking fact brought out in the maturity test relates to quality. The fruit from the first pick had an excellent flavor at the end of the longest storage period for that fruit, while the fruit in the last pick, irrespective of the orchards from which it came, was almost unfit to eat, although the physical appearance was very good.

SUMMARY OF THE PRUNE INVESTIGATIONS.

Prune growing is the principal horticultural industry in the section around Salem and in other districts of the Willamette Valley, Oreg. The entire product normally is evaporated.

If a portion of the crop could be successfully shipped in a fresh state it would be of distinct advantage, at least during certain seasons, in that it would furnish an additional outlet for the profitable disposal of the crop. If prunes could be successfully and profitably shipped in a fresh state it would stabilize the industry greatly and permit its further profitable development in this and other sections well adapted to prune growing.

Numerous attempts have been made to ship prunes fresh, but with rather indifferent success. These investigations, undertaken primarily to determine the practicability of fresh-prune shipment, indicate that by the exercise of proper care in harvesting and proper orchard-sanitation practices prunes can be successfully shipped in a fresh state to markets at least as far east as Chicago.

As with cherries, success in fresh-prune shipping is dependent upon the elimination of the decay occurring in transit and after arrival on the market, this decay being due either to mechanical abrasions or injuries in handling or to brown-rot with which the fruit has become infected before being removed from the trees.

The results, both commercial and experimental, indicate that unless a radical improvement is made in the methods of handling as well as in orchard-sanitation practices, entire dependence will have to continue to be placed on evaporation for the disposal of this crop.

Prunes can be picked, hauled, and packed with comparatively little injury and resultant decay, provided the utmost care in picking is exercised to avoid bruising the fruit in placing it in the pail, in transferring it to the orchard box, and in hauling it to the packing house.

The preservation of the bloom is also a very important consideration, and this goes hand in hand with care in handling to avoid injuries.

The fruits should be grasped by the pedicel and laid one at a time in the picking pail or bucket. The common practice of holding several prunes in the hand while picking results in rubbing off the bloom and in considerable bruising and injury, as does the equally common practice of dropping the fruit into either the picking bucket or field box.

In transferring the fruit to the field box the utmost care should be taken to prevent dropping or violent rolling, both with a view to preventing injury and bruising and to preserving the bloom.

The fruit should be kept in the shade while in the orchard and hauled to the packing house on wagons provided with good springs.

The load should be protected from the sun and dust by a canvas or other cover.

In packing, the utmost care should be exercised in culling out all imperfect or cracked fruit, as the inclusion of one or a few such fruits in a crate tends to spoil the whole crate and depreciates the value of the entire shipment.

Where possible, it is desirable to pack and grade directly from the lug box, in order to prevent the injury incident to pouring the fruit out on a packing table or into a bin.

The results of the investigations bring out strikingly the necessity for prompt loading, or for prompt cooling if the fruit is precooled.

The experiments fully demonstrate the value of precooling, provided it is thoroughly done. The money and time expended in precooling are largely wasted, however, unless the fruit is properly handled in harvesting and promptly precooled.

The results of the work during the shipping seasons of 1911 and 1913 conclusively demonstrate the necessity for more careful attention to orchard-sanitation practices if fresh-fruit shipment is to become uniformly successful and profitable. During seasons of adverse climatic conditions even the utmost care in handling will not serve to deliver the fruit on the market in uniformly sound condition unless it has been protected against infection by brown-rot in the orchards.

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WM. A. TAYLOR, Chief

Washington, D. C.



January 13, 1916

COMMUNITY PRODUCTION OF EGYPTIAN COTTON IN THE UNITED STATES.

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(constituting the Committee on Southwestern Cotton Culture).

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INTRODUCTION.

The purposes of this bulletin are to tell how Egyptian-cotton production became established in the Southwest as a result of community action, to describe the present status of the industry, and to give the reasons for encouraging the growing of this type of cotton in the United States. Attention is also directed to the conditions which appear to be indispensable to its successful commercial production in this country. It is believed that Egyptian cotton can not be profitably grown except under irrigation and in the absence of the boll weevil. This would exclude it from consideration in any portion of what is generally known as the cotton belt.

The principle of community action in cotton production implies the growing of only one variety, the variety selected being that which is best adapted to the physical and economic conditions of the locality.¹ In no other way is it possible to maintain a supply of pure seed and to market year after year a uniform high-grade product. These objects can be attained only by effective cooperation on the part of the growers. The lesson taught by this successful application of the community principle should make the present publication interesting to many who are engaged in growing, selling, or manufacturing cotton, even though they may not be concerned with the special subject of Egyptian-cotton production.

SOURCES OF LONG-STAPLE COTTON.

The three most important types of long-staple cotton are (1) Sea Island cotton, (2) long-staple Upland cotton, and (3) Egyptian cotton.

Sea Island cotton is grown on the islands along the coasts of South Carolina and Georgia and in certain counties on the mainland of Georgia and Florida, as well as to a limited extent in portions of the West Indies. During recent years the crop of Sea Island cotton in the United States has amounted to from 60,000 to 120,000 bales² per annum. The staple of Sea Island cotton ranges from $1\frac{1}{2}$ to $1\frac{3}{4}$ inches in the Georgia and Florida product to 2 inches in the best qualities grown on the Sea Islands proper.³

Long-staple Upland cotton has been for many years produced chiefly in the so-called Delta region of western Mississippi. In recent years the production of this type of cotton has been extended into eastern Arkansas and northeastern Texas, and a small quantity has also been grown in the Carolinas. Still more recently the growing of long-staple Upland cotton has been established on irrigated lands in the Imperial Valley of California, the industry in that locality being based on the Durango variety. The quantity of long-staple Upland cotton produced annually in the United States is not definitely known. A recent publication of the Bureau of Crop Estimates⁴ places the total at slightly more than 400,000 bales, although

¹ Cook, O. F. Cotton improvement on a community basis. *In* U. S. Dept. Agr. Yearbook, 1911, p. 397-410, 1912. See also Swingle, W. T., The fundamentals of crop improvement, in U. S. Dept. Agr., Bur. Plant Indus. Cir. 116, pp. 3-10, 1913.

² The Sea Island cotton bale averages in weight slightly less than 400 pounds. For further information, see Meadows, W. R., Economic conditions in the Sea Island cotton industry, U. S. Dept. Agr. Bul. 146, 18 p., 1914.

³ A small proportion of the island product reaches a length of $2\frac{1}{4}$ and rarely even $2\frac{1}{2}$ inches.

⁴ The Agricultural Outlook. U. S. Dept. Agr., Farmers' Bull. 651, p. 13, 1915. See also Taylor, Fred, and Sherman, W. A., Spinning tests of Upland long-staple cottons, U. S. Dept. Agr. Bul. 121, 20 p., 1914.

it is explained that this quantity probably includes chiefly cotton $1\frac{3}{8}$ inches and more in length. If the designation "long staple" be taken to comprise all Upland cotton having a staple of more than $1\frac{1}{8}$ inches in length, it is probable that the American production exceeds 1,000,000 bales annually. While a few varieties of long-staple Upland cotton sometimes produce fiber having a staple of $1\frac{1}{2}$ inches or longer, the bulk of the crop is less than $1\frac{3}{8}$ inches in length.

Egyptian cotton until very recently has been produced commercially only in the delta and lower valley of the Nile River, in Egypt. In recent years the Egyptian crop has amounted annually to the equivalent of about one and a half million 500-pound bales.

CHARACTER AND SUPPLY OF EGYPTIAN COTTON.

Egyptian cotton is a distinct type, both botanically and commercially, comprising several varieties and having a total range of staple of from $1\frac{1}{4}$ to $1\frac{5}{8}$ inches. The history of cotton growing in Egypt since the present definite type was developed in that country about 65 years ago has been marked by the successive appearance of numerous varieties. Each of these, after having been extensively grown for a number of years, has shown marked deterioration due to intercrossing.

The most striking characteristics of the Egyptian fiber are its length of staple combined with great strength and fineness. The older varieties, Ashmuni and Mit Afifi, are characterized by a brown or, more properly, pinkish buff color of the fiber, but the Sakellaridis variety, which is now highest in favor among spinners, is nearly white, or almost as light in color as Sea Island cotton.

Egyptian cotton is used especially in the manufacture of goods in which strength or fineness or a combination of both qualities is desired. Some of the principal articles manufactured from this cotton are sewing thread, hosiery, automobile-tire fabrics, and fine and fancy dress goods. Until a few years ago mercerized fabrics were made only from Egyptian cotton, but the process of mercerization has now been developed so that other cottons can be successfully treated. "Balbriggan" underwear was formerly manufactured exclusively from the brown Egyptian cottons, but dyed white cottons are now also employed for this purpose.

The cotton crop of Egypt is grown entirely on irrigated land in a climate which is practically rainless throughout the period of development of the cotton plants. The absence of rain during the picking season favors the production of clean cotton. The average yield for the entire cotton acreage in Egypt is about 435 pounds of lint per acre. The recent annual production of cotton in Egypt is shown in Table I.

TABLE I.—*Total production of cotton in Egypt, exclusive of the Sudan, for the past five years, in kantars and in the equivalent of 500-pound bales.*¹

Year.	Kantars.	500-pound bales.
1909.....	5,001,000	990,200
1910.....	7,505,000	1,486,000
1911.....	7,386,000	1,462,430
1912.....	7,499,000	1,485,000
1913.....	7,684,000	1,521,430

¹ The kantar equals 99.049 pounds. The Egyptian bale contains about 750 pounds, but for reader comparison the conversion is made in the table into the equivalent of the American bale of 500 pounds. The figures in the table are taken from those published by the Egyptian Ministry of Agriculture. (Mo. Return [Min. Agr. Egypt], year 3, no. 2, 16 p., Oct. 31, 1914.)

About 60 per cent of the entire Egyptian crop is exported to Great Britain and a smaller proportion to the United States (10 per cent in 1910 and 1911 and 13 per cent in 1912). The remainder is exported mainly to the countries of continental Europe.

AMERICAN CONSUMPTION OF EGYPTIAN COTTON.

Notwithstanding the fact that nearly two-thirds of the American cotton crop is exported for manufacture in foreign countries, a large and steadily increasing quantity of raw cotton is imported for manufacture in the United States. By far the larger part of this imported cotton is obtained from Egypt. Table II shows the imports of Egyptian cotton for the past 10 years. These figures are taken from those published by the Bureau of the Census.¹ They show that the quantity imported varies somewhat from year to year, but the tendency is toward an increase in the importations.²

TABLE II.—*Imports of Egyptian cotton for the crop-distribution years from 1905 to 1914, inclusive, stated as 500-pound bales.*

Year.	Quantity imported, in 500-pound bales.	Year.	Quantity imported, in 500-pound bales.
1905.....	108,283	1910.....	102,217
1906.....	103,669	1911.....	183,786
1907.....	169,731	1912.....	175,835
1908.....	120,187	1913.....	191,075
1909.....	129,985	1914.....	137,355

The shorter kinds of Egyptian cotton ($1\frac{1}{4}$ to $1\frac{3}{8}$ inch staple), the so-called brown Egyptian and Upper Egypt cottons, produced by the Mit Afifi and Ashmuni varieties, respectively, are used by

¹ Supply and distribution of cotton. Bureau of the Census [U. S.] Bul. 117 [1912]/13 40 p., 1913; Bul. 128 [1913]/14, 30 p., 1914. These bulletins have been published annually since 1905. The figures cover the crop-distribution year from September 1 to August 31, and hence refer to the crop produced in the previous calendar year.

² According to figures published by the Bureau of the Census, the total imports of Egyptian cotton for the 12 months ended July 31, 1915, amounted to the equivalent of 252,373 bales of 500 pounds each, as compared with 138,579 bales for the year ended July 31, 1914.

American manufacturers largely as a substitute for American long-staple Uplands of corresponding lengths, the substitution being profitable when the price of American long-staple cottons is relatively high. There is also a certain amount of substitution of the longest Egyptian, especially of the Sakellaridis variety, for the shorter lengths of Sea Island cotton, depending upon the relative prices of the two types. There remains, however, a large proportion of the imported Egyptian cotton for which no other fiber has yet been successfully substituted.

In view of this fact, the question has been frequently asked whether Egyptian cotton could not be produced in the United States in sufficient quantity to supply at least a part of the home demand. Conditions which have arisen in Egypt since the first attempts were made to answer this question have emphasized the importance of undertaking the production of Egyptian cotton in this country. It has been found that the maintenance of a uniform quality of any of the Egyptian varieties is rendered precarious by the fact that in Egypt distinct varieties are often grown in adjacent fields. There is also a general contamination of the whole Egyptian crop with an inferior and distinct type of cotton known locally as Hindi.

These conditions make it almost impossible to maintain in Egypt a supply of pure seed of a variety which has reached the stage of commercial production, because all these types of cotton cross freely with each other and adequate precautions are seldom taken to keep the seed of the different kinds separate at the gin. Furthermore, the cotton crop of Egypt suffers severely from insect enemies, notably in recent years from the ravages of the pink bollworm. This pest threatens a serious reduction of the crop, or at least a wide fluctuation in total production from year to year. Thus, it appears unsafe for the numerous American users of this type of cotton to depend solely upon Egypt for their supply of raw material, and the desirability of developing an independent source of supply in the United States is emphasized.

PRODUCTION OF EGYPTIAN COTTON IN AMERICA.

Although experiments with the production of Egyptian cotton in the southwestern United States were begun in 1902, it was not until 1912 that it was deemed advisable to recommend the commercial production of the crop. In the spring of that year seed was distributed by the Department of Agriculture to a number of farmers in the Salt River Valley in Arizona and the Imperial Valley in California. As a result of this distribution about 480 acres of cotton were brought through to harvest, and the crop of 1912 amounted to 375 bales of 500 pounds each.

In 1913 the production of Egyptian cotton was confined to the Salt River Valley, where a total of 3,800 acres was planted. Not all of this acreage came to harvest, but the crop for the year amounted to 2,135 bales of 500 pounds each.

In 1914 the area planted in the Salt River Valley amounted to approximately 12,000 acres. On much of this area the conditions were not favorable for large yields because of deficient soil fertility, inadequate preparation of the land, or faulty management of the irrigation. The total crop for the year amounted to 6,187 bales of 500 pounds each. While the average yield per acre shown by these figures is not high, a number of farmers having good land and using good methods obtained more than one bale per acre.

The status of the industry during the first three years of its existence is summarized in Table III.

TABLE III.—*Number of bales, estimated value of the lint, and estimated value of the seed of Egyptian cotton produced in the United States in the years 1912, 1913, and 1914.*¹

Year.	Cotton lint in 500-pound bales.	Estimated value of lint.	Estimated value of seed.	Estimated total value of crop.
1912.....	375	\$39,000	\$5,000	\$44,000
1913.....	2,135	197,000	28,000	225,000
1914.....	6,187	483,000	50,000	533,000

¹ Since 1913 the production of Egyptian cotton has been confined chiefly to the Salt River Valley in Arizona. A small quantity was produced in 1914 in the vicinity of Tucson, Ariz., but this is not included in the table.

Four ginning establishments, devoted exclusively to ginning Egyptian cotton, have been erected in the Salt River Valley. Each of these is equipped with 10 roller gins. The establishments are located in the towns of Phoenix, Tempe, Mesa, and Chandler. There are also two oil mills located at Phoenix, which press the seed of the Egyptian cotton crop of Arizona.

In staple and quality of fiber the American-grown Egyptian cotton is comparable with the best varieties produced in Egypt, and especially with the Jannovitch and Sakellaridis. The crops so far produced have also been of very good grade, comparing favorably with that of the best imported cotton. A large portion of the Egyptian cotton imported into the United States is of low grade or of relatively short staple, i. e., $1\frac{1}{4}$ to $1\frac{3}{8}$ inches. The American-grown Egyptian cotton does not come into competition with the latter class, but only with the better and higher priced varieties. However, the quantity of high-priced Egyptian cotton at present imported by American manufacturers very much exceeds the quantity likely to be produced in this country in the near future.

FUTURE POSSIBILITIES OF THE INDUSTRY.

Because of the low prices prevailing in 1914 only about 3,700 acres were planted to Egyptian cotton in the Salt River Valley in 1915. This check in the expansion of the industry is not to be regarded as wholly a disadvantage, since a continued rapid increase of the acreage might tax the resources of the growers' associations in providing sufficient pure seed for planting and in obtaining the labor necessary for prompt picking.

As to the ultimate possible extension of the industry, leaving out of consideration other localities where the climatic and soil conditions are favorable to the production of this crop, the Salt River Valley could produce as much as 50,000 acres annually. This is likely, however, only if prices remain at the average level of recent years and the supply of labor required for picking so large an acreage is obtainable. This is about the maximum acreage of cotton which a well-balanced agriculture in the Salt River Valley would permit unless the total acreage now under irrigation should be materially extended. The area of the Salt River Reclamation Project for which water is at present available is approximately 200,000 acres.

In view of the results obtained during the past three years, it appears to be conservative to estimate that 50,000 acres of land which have been enriched by crops of alfalfa and which are managed by farmers who have acquired experience in the best methods of growing Egyptian cotton would be capable of producing one bale per acre, or 50,000 bales from the entire area.¹ This quantity of cotton, selling at approximately 20 cents per pound, f. o. b. valley points (which is a reasonable figure if we consider the prices at which Egyptian cotton of corresponding quality has sold in the United States during the last 20 years), would yield to the growers approximately \$5,000,000 annually.

The foregoing statement refers to prospective production in the Salt River Valley, the only section of the United States in which Egyptian cotton has as yet found place as an established industry. It is not to be expected that this type of cotton can be produced commercially east of the Rio Grande, but there are other localities in the southwestern United States where the crop might be grown if economic conditions should justify a further extension of the acreage. It has been demonstrated through repeated experiments that the crop may be grown on the Yuma Reclamation Project on the lower Colorado River, which includes 100,000 acres, and in the Imperial

¹ This estimate presumes an average yield comparable to that hitherto obtained only by the more successful growers, but there is every reason to expect that with additional experience and more skill in handling the crop the average yields may be greatly increased.

Valley, Cal., which includes about 500,000 acres. If 20 per cent of the land in these two sections were to be used for Egyptian cotton, it is estimated that 100,000 bales might be produced annually, in addition to the 50,000 bales which the Salt River Valley could supply. While the production of Egyptian cotton appears to be possible to the extent indicated here, it seems unlikely that this crop will be grown in the Imperial and Yuma Valleys in the near future.

COMPARISON OF AMERICAN AND EGYPTIAN CONDITIONS.

The commercial production of Egyptian cotton in the United States involves the marketing of the product in direct competition with the crop of Egypt. This fact warrants a brief consideration of the status of the cotton industry in that country and a comparison between the conditions there and in the southwestern United States.¹ The production in Egypt of cotton having a staple comparable with that of the Salt River Valley product is limited to what is known as Lower Egypt, that is to say, the Nile Delta, north of Cairo. This region includes about 3,250,000 acres of irrigated land, of which about 40 per cent is annually devoted to cotton, with an average yield of about 450 pounds of lint per acre.

This land is heavily capitalized, and the cost of irrigation water is high. These features are best expressed by rental values, which range for the best land from \$50 to \$75 a year per acre. It is probable that the average rental value of land in Lower Egypt is not far from \$40 per acre, or at least twice the rental value of land in Arizona having similar capabilities of crop production.

While the cotton growers of Arizona have the advantage in respect to land rental or interest on land investment, those of Egypt are able to get their cotton picked at much less cost, owing to the cheapness and abundance of labor in that country. Aside from these two items, the cost of production is probably not very different in the two countries, since the low wage paid to farm laborers in Egypt is offset by the fact that the American farmer works with large fields and uses horse-drawn implements extensively. Much of the Egyptian crop, on the other hand, is grown by peasant farmers in small fields and with the use of very primitive implements.

The Egyptian industry suffers two serious disadvantages which do not exist in Arizona. One of these is the difficulty of maintaining pure seed, due to the widespread occurrence of Hindi, or "weed," cotton, which is discussed more in detail elsewhere in this paper. The other is the existence of certain insect pests, notably the pink

¹ For a more detailed discussion of the physical conditions in Egypt and in the southwestern United States, see Kearney, T. H., and Peterson, W. A., *Egyptian cotton in the southwestern United States*, U. S. Dept. Agr., Bur. Plant Indus. Bul. 128, 71 p., 2 figs., 5 pl., 1908.

bollworm, which have recently caused serious and extensive damage in Lower Egypt and which are still spreading.

It is probable that the higher valuation of land in Egypt, together with the less efficient methods of tillage, nearly or quite offsets the higher cost of labor in the United States. The crop-producing capabilities of the land in the two regions are much the same. The commercial value of the Arizona crop compares favorably with the best of the Egyptian crop and is much greater than the average value of the crop of that country. Finally, the Egyptian cotton grown in Arizona is practically free from Hindi contamination, and the pink bollworm has not yet found its way into the American fields.

In the matter of transportation the Egyptian cotton crop enjoys certain natural advantages over the product of the new American industry. It also has the advantage of long-standing occupation of the market and of a well-organized, though rather expensive, system of commercial distribution.

The entire Egyptian crop is assembled in Alexandria, where it is sorted, classed, compressed, and forwarded. Practically none of the cotton is manufactured locally. This centralization of the marketing business permits, though it does not insure, efficiency and economy in the handling of the product. The freight rates from Alexandria to manufacturing centers, transportation being by water, are low in comparison with the rates from Arizona, which include a long rail shipment. Freight rates, particularly ocean freight rates, are subject to continual fluctuations, but it is probable that the rates from Arizona to manufacturing points in either America or Europe are about three times as high as from Egypt to the same points.¹

The large volume of the Egyptian crop and the centralized methods of handling also permit a standardization of types and a system of future selling against these types which are very important commercial advantages. To find favor in the market a consignment of cotton must not only show good grade and good staple, but must represent a type which has had its merit established through actual use. A manufacturer having determined what types of cotton meet his particular requirements will endeavor to duplicate these types in his annual purchases. For this reason Egyptian brokers establish definite types and maintain them from year to year. This system of dealing on types is possible with the Egyptian crop in spite of the continued deterioration of the varieties, because each broker has a large volume of cotton offered to him at Alexandria from which to select his stocks.

¹ The Arizona cotton is usually shipped by rail to Galveston, Tex., and thence by water to New England. The freight rate on baled cotton from Salt River Valley points to New England is about \$1.30 per 100 pounds, this rate including the charge for compressing in transit.

The American growers will need to recognize this feature of the market for Egyptian cotton if they expect to secure full value for their product. While the American crop remains small, it is of the utmost importance that the quality be kept uniform from year to year.

It is possible to maintain this uniformity of type in the American crop if the growers exercise proper care in the selection of seed for planting. Unless the seed is selected carefully and consistent effort is made by good tillage and careful picking to maintain uniformly high quality in the crop, it will be difficult, if not impossible, to maintain the new industry on a profitable basis.

EARLY ATTEMPTS TO ESTABLISH EGYPTIAN-COTTON GROWING IN THE UNITED STATES.

The Department of Agriculture on several occasions prior to 1900 imported seed of Egyptian cotton and distributed it in small lots to farmers throughout the cotton belt. This procedure did not result in establishing the industry in any locality, a fact that ceased to be surprising when the necessity for community action in the commercial production of a new type of cotton came to be appreciated. The tests of the imported seed in various localities gave varying results as to yield and quality of the fiber produced, but serious difficulties were always encountered in communities where Upland cotton was already being grown. Some of these difficulties may be stated as follows:

- (1) Pickers disliked the small bolls, which made it appear that picking would be much more difficult and expensive than in the case of the big-bolled Upland types which are generally popular in the South.
- (2) Only saw gins were available for separating the fiber from the seed, and as a result the fiber was invariably injured in ginning.
- (3) Marketing small lots of a new type of fiber, with which the local buyers were unfamiliar, was found to be extremely difficult.
- (4) The Egyptian cotton was grown in the neighborhood of fields of Upland cotton, and consequently it was found impossible to keep the seed pure.

The seed of several of the best varieties grown in Egypt was imported in larger quantities by Mr. David Fairchild following his visit to that country in 1900 as an agricultural explorer for the Department of Agriculture.¹ Dr. H. J. Webber, then in charge of the plant-breeding work with cotton in the Department of Agriculture, undertook systematic tests of these varieties during the next two or three years at various localities in the cotton belt and in irrigated districts of the Southwest. In the main cotton belt fairly favorable

¹ The first planting of Egyptian cotton in Arizona appears to have been made with some of this seed, which was sent to Dr. A. J. Chandler, of Mesa, Ariz. This was a year or two before the beginning of experimental work with this crop in Arizona by the Department of Agriculture.

results were obtained in certain localities, but owing to the difficulties mentioned the experiments did not result in the establishment of commercial production.

BEGINNING OF EXPERIMENTS IN THE SOUTHWEST.

The irrigated lands of southern Arizona and southeastern California, where the climatic conditions more nearly resemble those of Egypt than in the cotton belt, were found to offer the most promising field for the introduction of this type of cotton. In the early stages of the work, however, serious difficulties were encountered in this region also. The most important of these were the following: (1) The lack of proper facilities for carrying on the plant-breeding work and the investigations of cultural methods; (2) lack of uniformity in the imported stocks of seed and slow progress in the development of a productive type having fiber of sufficiently good quality and uniformity to warrant its recommendation for commercial production; and (3) lack of information as to the proper methods of irrigation and culture under the climatic and soil conditions of the region.

It also became apparent that, even if these cultural difficulties could be overcome, certain economic problems would need to be solved before commercial production could be undertaken with any hope of success. These problems were as follows: (1) The scarcity and high price of labor in this thinly populated region, which threatened to make the picking so expensive that no profit could be anticipated; and (2) the difficulty of ginning and marketing the crop grown in a small way by farmers in localities remote from established cotton markets.

The first-mentioned difficulty was overcome when the Department of Agriculture established two well-equipped experiment farms where the plant-breeding work and the study of cultural methods could be carried on from year to year on the same soils and under the same management. These farms are the Cooperative Testing and Demonstration Garden at Sacaton, Ariz., with Mr. E. W. Hudson as superintendent, conducted by the Office of Crop Physiology and Breeding Investigations in cooperation with the Office of Indian Affairs, Department of the Interior, and the experiment farm at Bard, Cal., on the Yuma Reclamation Project, formerly in charge of Mr. W. A. Peterson and at present under the superintendence of Mr. R. E. Blair, conducted by the Office of Western Irrigation Agriculture in cooperation with the United States Reclamation Service.¹

¹ Mr. Argyle McLachlan served for several years as field agent of the Department of Agriculture in the Southwest, and while his attention was devoted mainly to the Durango-cotton industry in the Imperial Valley, he also aided effectively in the work with Egyptian cotton in the Salt River Valley.

UNSATISFACTORY CHARACTER OF THE ORIGINAL STOCKS.

During the earlier years of the breeding work in Arizona the behavior of the plants was very unpromising. They made an extremely rank growth, but were relatively unfruitful and late in maturing. The bolls were small and often opened imperfectly. There was also a pronounced lack of uniformity in the imported stocks and in the strains which were first selected from them.¹

Mr. O. F. Cook, as a result of observations upon Egyptian varieties grown in Arizona from newly imported seed, reached the conclusion that the difficulty in obtaining uniformity was largely attributable to the presence among the Egyptian stocks of a very different and inferior type of cotton, the Hindi, the resulting cross-pollination having led to serious contamination of the Egyptian varieties. The matter seemed of sufficient importance to warrant an investigation in Egypt by Mr. Cook in 1910. The degree of Hindi contamination observed in that country was surprisingly great.²

Nearly every cotton field inspected was found to contain Hindi plants, and in some fields as many as 20 per cent of the plants were of the Hindi type. The percentage of pure Hindi plants does not represent the full extent of the damage, since this type crosses readily with the Egyptian cotton and the final result is a series of hybrids possessing in varying proportions the characters of each parent. Commencing with a mixed population of this sort, a uniform cotton can be developed only by the selection of an individual plant which possesses the characters desired and which breeds true, thus permitting the segregation of a pure stock.

Even if there were no Hindi cotton in Egypt, the conditions would be unfavorable for the maintenance of uniform varieties, since a number of distinct types of Egyptian cotton are grown, often in adjacent fields, and the pollen is readily carried from field to field by insects, leading to the production of intervarietal hybrids. Furthermore, until very recently no adequate precautions were taken to avoid the mixing of seeds at the gins.

DEVELOPMENT OF MORE UNIFORM VARIETIES.

Success in the effort to obtain a variety which could safely be recommended for commercial production was not attained until the variety called "Yuma" was segregated in 1908.³ Although selected

¹ Cook, O. F., McLachlan, Argyle, and Meade, R. M. A study of diversity in Egyptian cotton. U. S. Dept. Agr., Bur. Plant Indus. Bul. 156, 60 p., 6 pl. 1909.

² Cook, O. F. Hindi cotton in Egypt. U. S. Dept. Agr., Bur. Plant Indus. Bul. 210, 58 p., 6 pl. 1911.

³ For a more complete description of this variety and a more detailed account of its history, see Kearney, T. H., Breeding new types of Egyptian cotton, U. S. Dept. Agr., Bur. Plant Indus. Bul. 200, 39 p., 4 pl., 1910. See also Kearney, T. H., Mutation in Egyptian cotton, in Jour. Agr. Research, v. 2, no. 4, p. 287-302, pl. 17-25, 1914.

from a stock of Mit Afifi, the Yuma cotton is very distinct from that variety in the characters of the plants and of the fiber. The lint averages $1\frac{1}{2}$ inches in length (ranging, under different cultural and soil conditions, from about $1\frac{7}{16}$ to about $1\frac{9}{16}$ inches) and has the pale pinkish buff color of the Jannovitch rather than the deeper buff color of the Mit Afifi. The lint percentage averages about 28.

Yield tests and spinning tests of the Yuma cotton carried on during several years demonstrated that a stable variety, uniform in its characters and producing fiber of good spinning quality, had at last been obtained. Seed was therefore placed in the hands of farmers in the Salt River and Imperial Valleys in 1912, with the results described on preceding pages.

From the Yuma variety there has originated another very distinct new type, which has received the name "Pima" and which surpasses the parent variety in productiveness, size of the bolls, and length and quality of the fiber. Yield tests of the new variety and spinning tests of its fiber are now in progress, and if the results bear out the early promise it may be advisable to substitute this variety for the one which is now grown commercially.

MAINTAINING THE PURITY OF THE VARIETY.

The immediate progeny of the individual plant from which the Yuma variety originated was remarkably uniform, except that about 8 per cent of the plants were evidently first-generation hybrids. The presence of these hybrids could readily be explained by the fact that some of the flowers on the parent plant had been fecundated with pollen from surrounding Egyptian cotton plants containing more or less Hindi blood and from Upland cotton plants grown near by. Seeds from the apparently nonhybrid plants in this progeny were used to plant a 4-acre field of the Yuma variety in 1909. Although these plants had shown only the characters typical of the new Yuma variety, about 2.5 per cent of their progeny of 1909 exhibited, more or less distinctly, Hindi or Upland characters. All such plants were rogued out of the field early in the summer, at about the time blossoming commenced.¹

The vegetative characters of the Yuma variety are distinctive and the recognition of hybrids is comparatively easy. It is therefore practicable to remove most of the "off-type" plants at a sufficiently early stage of their development to prevent their crossing with the typical plants. Careful roguing of the seed-increase fields year after year

¹The importance of the early roguing of cotton fields intended to furnish seed for planting and the feasibility of recognizing the "off-type" plants in the early stages of growth have been pointed out by Mr. O. F. Cook. (Cotton selection on the farm by the characters of the stalks, leaves, and bolls. U. S. Dept. Agr., Bur. Plant Indus. Circ. 66, 23 p. 1910.)

has made it practicable to maintain thus far a satisfactory degree of uniformity in the variety.

SOLVING THE PROBLEMS OF COMMERCIAL PRODUCTION.

As the work of establishing the new industry progressed it became apparent that the economic and agricultural problems could best be met by enlisting the cooperation of several men representing different lines of experimental work in the Department of Agriculture, each of whom was able to contribute special knowledge and experience. The cooperation was at first informal, but later, as the responsibilities increased, it was thought advisable to create a special committee to carry on this work. A "Committee on Southwestern Cotton Culture" was therefore appointed in 1910 by the Chief of the Bureau of Plant Industry.¹

It has been the policy of the committee since its organization to avoid a sharp segregation of the different fields of investigation. As a result, each member has felt free to offer suggestions and even to assume responsibility beyond the limits of his own field, while the more important issues which have successively arisen in connection with the establishment of the industry have been decided by the whole committee. It is believed that this committee cooperation has been of the greatest importance in the successful establishment of the industry, since it has resulted in focusing upon the problems the different points of view and different mental equipment and training of several independent investigators.

¹ The following is the personnel of the committee:

C. S. Scofield, Agriculturist in Charge of Western Irrigation Agriculture. Mr. Scofield is chairman of the committee, and in addition has charge of those phases of the work which involve cooperation with the United States Reclamation Service. He has also conducted certain investigations of market conditions in the United States and in Europe.

W. T. Swingle, Physiologist in Charge of Crop Physiology and Breeding Investigations. Mr. Swingle has charge of those phases of the work which involve cooperation with the Office of Indian Affairs, including the arrangements for securing Indian labor. The Co-operative Testing and Demonstration Garden at Sacaton, Ariz., where plant-breeding work with cotton is now centered, is under Mr. Swingle's direction. Mr. E. W. Hudson, superintendent of this garden, has taken a very active part in the establishment of the industry and has been in constant touch with the growers in the Salt River Valley.

O. F. Cook, Bionomist in Charge of Crop-Acclimatization and Cotton-Breeding Investigations. Mr. Cook conducts investigations of the factors involved in the acclimatization of different types of cotton in the Southwest and of the relation of these factors to cultural methods. He has also taken the lead in developing the idea of community cotton growing as a means to the maintenance of uniform varieties.

T. H. Kearney, Physiologist in Charge of Alkali and Drought Resistant Plant Investigations. Mr. Kearney has charge of the breeding work with Egyptian cotton and of the investigations of the effect of alkali and other soil conditions upon the production of this crop.

C. J. Brand, Chief of the Office of Markets and Rural Organization. In 1912, when the problem of marketing the first commercial crop became acute, Mr. Brand, at that time in charge of the cooperative cotton handling and marketing investigations of the Bureau of Plant Industry, became a member of the committee. Mr. Brand has charge of the investigations in classing, marketing, and transportation.

Cooperative action having thus been provided, the economic problems were attacked as follows:

(1) The principle of community action in cotton production, being thoroughly recognized, was successfully applied in the organization of associations of growers through which the problems of cooperative ginning and marketing were solved.

(2) A very satisfactory supply of labor was developed through the employment of Pima and Papago Indians as cotton pickers, the first experiments having been made at the Cooperative Testing and Demonstration Garden at Sacaton, under Mr. Swingle's direction.

(3) Methods for classing the new product were worked out and a series of grade types was established, under Mr. Brand's direction, by Mr. J. G. Martin, investigator in cotton marketing.

(4) The American and European markets for this type of cotton were investigated by representatives of the associated growers and of the Department of Agriculture, contacts with buyers and spinners were established, and outlets for the product on the basis of full market value were thus assured.

(5) In cooperation with the associated growers, measures were taken to insure a supply of pure seed for planting each year.

COOPERATIVE ORGANIZATION OF THE GROWERS.

When the Yuma variety of Egyptian cotton developed by the Department of Agriculture had been shown to possess the qualities needed for successful commercial production, it was pointed out that the industry could be successfully established only by community action and that the department stood ready to furnish a supply of seed for planting, provided the growers were able to form a cooperative association. Farmers in the Salt River Valley had watched with interest the experiments with Egyptian cotton at Sacaton and had conferred with the superintendent of the cooperative garden there regarding the outlook for commercial production and the methods of growing the crop. They were therefore ready to adopt the point of view of the department, and in the spring of 1912 about 30 farmers in the vicinity of Mesa organized an association. In the following year similar organizations were formed at Chandler and Tempe. Finally, in the spring of 1914, a central organization, known as the Salt River Valley Egyptian-Cotton Growers' Association was formed, with the Mesa, Chandler, and Tempe associations as its constituent members. The central organization was designed to look after the marketing of the crop and the maintenance of a supply of pure seed for the entire valley, while the local organizations continued to provide for the ginning of the cotton grown by their members and for financing the crop during the growing period.

The Mesa and Tempe associations now operate well-equipped ginning plants. The gin at Chandler has been leased and operated by a private company, and there is also a privately owned ginning plant at Phoenix.

The organization of the cotton growers of the Salt River Valley is still far from complete, since in 1911 only about 40 per cent of the total acreage of Egyptian cotton was represented in the central association. It is not likely, nor is it necessary to the success of the industry, that all of the growers in a community will become active members of the cooperative growing and marketing associations, but it is of the utmost importance that all should adhere to the policy of the organizations as regards the production of a single variety and the use of carefully selected seed. The commercial reputation of the cotton produced in the region, and hence the best interests of every individual cotton grower, can be secured only by this means.

LABOR FOR PICKING.

From the beginning of the experiments with Egyptian-cotton production in the Southwest it has been realized that the high cost of picking would be one of the most difficult problems to overcome. Hand labor is neither abundant nor cheap in these southwestern irrigated districts, yet a cheap and abundant supply of hand labor has generally been regarded as essential to successful cotton production. Picking Egyptian cotton requires greater care and is more expensive than picking Upland cotton, owing to the smaller size of the Egyptian bolls and the necessity of avoiding an admixture of such trash as leaves and pieces of bolls. In picking long-staple cotton it is especially important to keep the seed cotton clean; otherwise the grade of the lint is impaired and its selling value is much reduced. The cotton growers of the Salt River Valley have had to pay for picking at the rate of \$2 per 100 pounds of seed cotton, while in the Imperial Valley, where big-bolled types of cotton are grown, the prevailing rate has been \$1 per 100 pounds.

Notwithstanding these natural disadvantages, the problem of picking the crop of the Salt River Valley has been met successfully. It has been found that pickers could make satisfactory wages when paid at the rate mentioned. Although the industry has developed rapidly, no serious shortage of labor has yet been experienced. This has been due to the fact that the growers, through an active organization, have attacked the problem in a businesslike way. In the first place, many of the farmers had only small acreages and they and their families were able to do most of the picking. This distribution of the acreage among small farmers is very desirable and should be encouraged. There remained, however, a large acreage for which pickers had to be secured, in addition to the home supply of labor. For this purpose the floating population of the valley was drawn upon and Indians were brought in from near-by reservations.

There are two tribes of Indians in southern Arizona which include a large number of industrious and capable workers. The Pimas, who

occupy a reservation adjoining the Salt River project, have taken up cotton growing to some extent on their own lands and have also been employed as cotton pickers by the white settlers. The Papagos occupy a large tract of land lying south of the Pima Reservation. There are several thousands of these Indians, and as they lead a rather nomadic existence because of the uncertainty of the desert water supply, they find a season of cotton picking a congenial method of employment and have taken to it readily. Last year several hundred of them were engaged in the work throughout the picking season, with very satisfactory results to themselves and to the cotton growers.¹

The present indications are that if the cotton acreage in the Salt River Valley does not increase too rapidly and if the growers continue to give the problem the attention it deserves, there will be no serious shortage of pickers. While the cost of picking is high, the other costs of production are not excessive, and if the yields are good the value of the crop is sufficiently great to carry the picking cost and leave a satisfactory margin of profit to the grower.²

COMMUNITY CREDIT FOR FINANCING THE CROP.

The production of cotton in a new region involves some arrangement for financing the crop until it can be sold. The expenses of production up to the time of picking are not much greater than with other farm crops, but ordinarily the pickers must be paid promptly, and the cost of picking, together with the cost of ginning, requires an outlay of funds greater than farmers can ordinarily meet without special credit arrangements. This is particularly true when cotton growing is being undertaken in a new region, because the marketing of the crop takes more time than when the industry is well established. Under such conditions the crop can rarely be sold as soon as it is ginned. It must be classed and assembled into uniform lots, and must move to market gradually if the best prices are to be obtained. Even in the case of the well-established cotton industry in Egypt the crop moves to the market very gradually, much of it not reaching the manufacturer until the following spring or summer. Meanwhile, it must be financed.

¹ It is estimated that in 1913 about \$20,000 and in 1914 about \$37,500 was paid to Indians of the Papago and Pima tribes as wages for picking cotton in the Salt River Valley. These sums, in addition to what was derived from the sale of the crops grown on the reservation lands, indicate that the combined income from Egyptian cotton which accrued to the Indians of southern Arizona approximated \$40,000 in 1913 and \$50,000 in 1914.

² The extent to which the money brought into the locality by this new crop is distributed among the population is indicated by the estimate that during the picking season of 1914-15 a total of \$150,000 was paid out in wages to cotton pickers in the Salt River Valley.

In view of the uncertainties attending the marketing of long-staple cotton from a new locality, brokers are not likely to risk paying what they believe to be the full value of the crop if asked to take it unclassified in round lots, as it comes from the gin. For that matter, even when they have the advantage of a well-established market, farmers would probably benefit by holding their cotton in storage until it can be classed into even-running lots and sold with the least element of risk to the cotton merchant or the spinner.

The associated growers in the Salt River Valley have met this problem of financing the crop by a plan of community credit. Arrangements were made with local banks to secure the necessary funds. Each bale of cotton, as soon as it was ginned, was placed in storage and a receipt was issued against it, these receipts being used as collateral for loans through the association. In this way it was possible for the grower to secure money to defray his expenses for picking and ginning without losing possession of his cotton until it was finally sold to the manufacturer. In the absence of such a system of community credit, it probably would have been necessary for the grower to sell his cotton as soon as it was ginned for whatever price he could obtain.

GINNING IN RELATION TO PRODUCTION.

The roller gin which is used for Egyptian cotton can not be operated as rapidly or as cheaply as the saw gin which is used for Upland cotton. The charge ordinarily made for ginning Egyptian cotton in the Salt River Valley is \$10 per bale, which is more than twice as much as is charged for ginning Upland cotton in the South. The actual cost of ginning Egyptian cotton in Arizona is probably less than the figure specified, and is likely to be materially reduced through the adoption of certain improvements in the machinery.

Instead of depending upon custom ginning, two of the associations of cotton growers in the Salt River Valley operate their own plants. The experience of these farmers, which is in accord with that of farmers in the eastern cotton belt, indicates that the best results are obtained when the ginning is under the control of the producers. The market value of cotton may be very greatly reduced by careless ginning, and when the gin operator has no other interest than to secure the largest possible outturn, the commercial value of the product is likely to be impaired.

Cotton ginning is a technical operation, which requires experience and skill to secure the best results. The cooperative ownership and management of a gin by the growers does not in itself insure capable and efficient management, but it does afford the owners of the crop an opportunity to insist upon the work being properly done. This

opportunity is seldom afforded when the cotton is handled by custom gins. In either case, it is of the utmost importance to the growers that the crop be classed or graded by a capable and impartial expert as soon as it leaves the gin. Prompt grading serves to warn the farmer if either the picking or ginning is being poorly done, and gives him this warning in time to enable him to secure better work.

The grower is interested in the way the ginning is done, not only because of its effect on the value of his lint, but also because of its relation to his supply of seed for planting. Where only uncontrolled custom ginning is available the grower has small chance of maintaining the purity of his seed.¹

The opinion appears to be gaining ground among students of cotton production that the improvement of the industry depends fully as much upon good ginning as upon good cultivation or good picking. The surest way to obtain good ginning is by cooperative ownership and operation of the gins.

GRADING THE CROP.

It was pointed out on a preceding page that uniform grades of Egyptian cotton must be established and maintained from year to year if the crop is to find ready sale at its full value. In recognition of this fact steps were taken in 1913 to establish standards of the different types and grades produced in the crop of that year. A cotton-grading expert was detailed from the Office of Markets and Rural Organization to cooperate with the growers' association for this purpose. The work was continued in 1914, the standards having been perfected and arrangements having been made for spinning tests, in order that the cotton might be placed on a sound basis of market value. The scope and results of this standardization work are given in a report from the Office of Markets and Rural Organizations.²

MARKETING THE CROP.

Notwithstanding the facts that the Egyptian type of cotton has not been grown previously on a commercial scale in the United States and that the Salt River Valley is a new cotton-growing locality, comparatively little difficulty has been experienced thus far in disposing of the product. This is due largely to the cooperative action of the growers in grading and marketing their cotton, which has made it possible for them to offer it in uniform lots of sufficient size

¹ Experiments that demonstrate in a striking manner the readiness with which seeds of different varieties of cotton become mixed in commercial ginning establishments have been described recently by D. A. Saunders and P. V. Cardon. (Custom ginning as a factor in cotton-seed deterioration. U. S. Dept. Agr. Bul. 288, 8 p., 5 fig. 1915.)

² Martin, J. G. The handling and marketing of the Arizona-Egyptian cotton of the Salt River Valley. U. S. Dept. Agr. Bul. 311, 16 p., 3 pl. 1915.

to interest the buyers. Another factor has been the willingness of progressive manufacturers who recognize the need of developing new sources of long-staple supply to purchase and try out this cotton while its production was still in the experimental stage.

The few hundred bales produced in 1912 were readily disposed of at good prices, being purchased by a firm of thread manufacturers. In 1913 the dull condition of the cotton market and the lack of established contracts between the growers' associations and the spinners of staple cottons retarded the disposal of the much larger crop. The portion of the crop controlled by the associated growers was, however, finally sold on satisfactory terms through a large international firm of cotton buyers, which sent an agent to Arizona to superintend the purchase and shipment of the crop.

In 1914 the same cotton-buying firm, which has shown a constructive interest in the development of Egyptian-cotton growing in the Salt River Valley, again handled a large proportion of the crop, and it was moved out promptly, either on actual sale or on consignment, as fast as it was ginned and classed. On the other hand, some of the individual growers who did not belong to the cooperative associations experienced difficulty in disposing of their cotton.

It should be noted that ever since the establishment of the industry the crop has been sold each year in open competition with the vastly larger crop produced in Egypt. The effective organization of the Arizona growers and the intelligent application of the best principles in growing, handling, and marketing the crop and in maintaining the seed supply are largely responsible for this satisfactory result.

MAINTENANCE OF THE SEED SUPPLY.

It was pointed out in an earlier publication¹ what steps should be taken by the associated growers and what kind of assistance the Department of Agriculture could furnish in guarding against the deterioration of the seed used for planting.

The growers having signified their desire to cooperate with the department along these lines, experts were detailed during the summer of 1913 to rogue a limited acreage of well-grown cotton in order to obtain seed for increase during 1914 and for general planting in 1915. In 1914 the department's experts, assisted by representatives of the Salt River Valley Egyptian-Cotton Growers' Association, rogued about 100 acres which had been planted with seed from the fields which were rogued in 1913. Every plant in this acreage was examined, and the unproductive and off-type plants, amounting to about 1 per cent of the total, were removed. The

¹ Kearney, T. H. Seed selection of Egyptian cotton. U. S. Dept. Agr. Bul. 33, 8 p. 1913.

work was done early in July, soon after blossoming began, in order to take out the inferior plants before their pollen should contaminate those left in the field. Of the cotton grown from seed produced by fields which were rogued in 1914, about 100 acres were rogued during the summer of 1915, somewhat less than 1 per cent of the plants being removed.

The association undertakes to have the seed from the rogued fields ginned under such conditions as to avoid mixing with other seed and also to have the seed sacked and tagged as it comes from the gins, in order to prevent mixture while it is held in storage. The rogued seed is placed by the association in the hands of careful farmers having good land sufficiently remote from other cotton to prevent crossing. The fields planted under these conditions are inspected during the summer, and the product of those which are properly grown and are otherwise satisfactory is ginned separately, in order to furnish seed for general planting the second year after the roguing is done. Thus, the seed used for general planting in 1916 will be derived from the fields which were rogued in 1914, and that which is used for general planting in 1917 will be derived from the fields rogued in 1915. It is believed that the seed from inspected fields can be sold for planting at a price very little above current oil-mill prices, thus removing the temptation to plant unselected seed because it is cheaper.

If the growers' association follows year after year the plan thus outlined it is to be expected that deterioration, if it occurs, will be so gradual that there will be time for the substitution of a pure strain selected and multiplied at the plant-breeding station.

AGRICULTURAL RELATIONSHIPS OF THE CROP.

The outstanding agricultural feature of cotton production in Arizona is the value of the crop in the farm rotation. Alfalfa, which occupies more than half the irrigated land in the Salt River Valley, is the basis of the agriculture of that locality; but the alfalfa fields after a few years become so badly infested with Bermuda grass and other weeds that their value is greatly impaired. It has been found that these old alfalfa fields, when thoroughly broken up and worked into good tilth, yield large crops of cotton. At the same time the intertillage of the cotton crop while the plants are young and the complete shading of the ground later in the summer effectually rid the land of weeds. One or two well-tilled crops of cotton following alfalfa will leave the land clean and in excellent condition for re-seeding with alfalfa or for growing other crops. Because of its renovating value in the farm rotation, cotton is a valuable crop for the Salt River Valley, quite aside from the cash returns it brings.

Less water is needed for the production of cotton than for the production of alfalfa, particularly early in the season. In fact, the total seasonal quantity of water needed for irrigating cotton is probably not much more than half that needed for the irrigation of alfalfa. The significance of this point lies in the fact that there is more irrigable land in the Salt River Valley than can be supplied with irrigation water. Hence, the growing of a crop which permits economy of the water supply may permit the ultimate extension of the irrigated area.

A portion of the irrigated land in the Salt River Valley has been damaged by the excessive irrigation of alfalfa, which has resulted in the land becoming swampy. While this trouble has not been serious, it has occasioned anxiety on the part of certain landowners and has necessitated the formulation of plans for a drainage system. The growing of cotton on these areas tends to reduce the danger of waterlogging.

Another advantage of cotton as a crop for the irrigated Southwest is the fact that the product is a staple and nonperishable commodity. Practically all of the other crops yielding high cash returns per acre are perishable and involve the hazard of heavy losses if the market is temporarily oversupplied. Cotton, on the other hand, is not subject to rapid deterioration if not sold promptly.

COST OF PRODUCTION.

In an earlier report on the Egyptian-cotton industry in the Southwest,¹ the various factors involved in the cost of production were discussed, and the conclusions stated were as follows:

The cost of producing an acre of Egyptian cotton, estimating a yield of 1,800 pounds of seed cotton per acre, may be summarized as follows: Seed, tillage, and irrigation, \$15; picking, \$36; ginning and baling, \$10; making a total cost of \$61 per acre, exclusive of interest on land investment. It should be kept in mind that these figures are merely approximations. The actual costs will be found to vary between wide limits, both above and below these figures.

After two years' additional experience, an estimate of the cost of production has been prepared by Mr. W. S. Dorman, who has grown the crop for three years and who has also served as president of one of the local associations of growers, a position which has enabled him to keep in close touch with the progress of the new industry. Mr. Dorman's estimates are shown in Table IV.

From these estimates, which include the item of interest on the land investment and deduct the value of the seed produced, Mr. Dorman has calculated the net cost of production per pound of lint

¹ Scofield, C. S. Egyptian cotton culture in the Southwest. *In* U. S. Dept. Agr., Bur. Plant Indus. Circ. 123, p. 21-28, 2 fig. 1913.

as 16.54 cents when the yield is two-thirds of a bale per acre, and 13.65 cents when the yield is one bale per acre.

TABLE IV.—*Cost of producing Egyptian cotton in the Salt River Valley based on yields of two-thirds of a bale and 1 bale to the acre.*

Item of cost.	Cost per acre of—	
	Two-thirds of a bale.	One bale.
Plowing, preparing soil, cultivating, and seed.....	\$15.00	\$15.00
Irrigation water.....	1.50	1.50
Picking seed cotton.....	24.00	36.00
Transportation to gin.....	2.50	3.00
Ginning lint, at 2 cents per pound.....	6.72	10.00
Interest on \$150 at 8 per cent.....	12.00	12.00
Total cost.....	61.72	77.50
Value of cotton seed at 75 cents per 100 pounds.....	6.15	9.26
Net cost of lint.....	55.57	68.24

The estimates given probably approximate very closely the average cost of producing Egyptian cotton in the Salt River Valley and show clearly the importance of securing large yields per acre if the industry is to be profitable. This fact is still further emphasized by the following statement (Table V) of the actual expenditures of a grower who, in 1914, produced cotton on a 40-acre field which yielded nearly 1½ bales per acre. The crop was produced entirely by hired labor.

TABLE V.—*Cost per acre of producing 40 acres of Egyptian cotton in the Salt River Valley in 1914.*

Item of cost.	Cost per acre.
Seed and tillage.....	\$15.10
Irrigation water.....	2.00
Picking 2,552 pounds of seed cotton, at 2 cents.....	51.04
Ginning, insurance, yardage, and association expenses.....	15.98
Interest and taxes.....	17.25
Total cost.....	101.37
Receipts for cotton seed.....	10.32
Net cost per acre.....	91.05
Yield of cotton lint per acre, 736 pounds; net cost of lint per pound.....cents..	12.37

¹ This figure of cost of production per pound of lint is not directly comparable with those arrived at by Mr. Dorman on the basis of yields of two-thirds of a bale and of one bale per acre, respectively, certain elements in the cost of production, notably land valuation (interest and taxes), having been differently estimated in the present instance.

This field gave one of the highest yields obtained in the Salt River Valley in 1914. It is a much larger yield than can be expected as an average from even the better lands. The figures are given here merely to indicate the importance of using the best methods of tillage

and irrigation if reasonable profits are to be obtained from the production of this crop. Even with the abnormally low prices obtaining last year, this farmer made a fair profit on his investment.

TILLAGE METHODS.

The best methods of preparing the land for Egyptian cotton and of irrigating and cultivating the crop have been worked out by Mr. E. W. Hudson, superintendent of the Cooperative Testing and Demonstration Garden at Sacaton, Ariz., and are described by him in a recent publication of the Department of Agriculture.¹

The essential features of these methods consist in the early and thorough preparation of the land; careful leveling, so that the entire field can be irrigated uniformly; early planting; getting the seed into moist soil; late thinning; leaving the plants close together in the row; the sparing use of irrigation water until the plants blossom; thorough cultivation as long as the size of the plants permits; and frequent light irrigation after blossoming begins until the crop is fully matured.

LATE THINNING AND CLOSE SPACING.

The Egyptian-cotton plant makes a very luxuriant growth on the irrigated lands of the Southwest. Because of this fact, it was thought necessary at first to plant the rows wide apart (as much as 5 feet) and to thin severely, leaving the plants finally $2\frac{1}{2}$ to 3 feet apart in the row. Under these conditions each plant attained a large size and produced several long vegetative branches, or "limbs." It was also customary at first to do the thinning, or "chopping" as it is called, when the plants were very small and had only two or three leaves in addition to the seed leaves. While this system of planting and thinning gave good yields, it was found that the crop was so late in maturing as to be in danger of frost injury in the autumn, and also that the large size of the plants and their numerous vegetative branches made the picking very difficult and expensive.

Closer investigation of the branching habits of the plant developed the fact that these troublesome vegetative branches could be suppressed by delaying the thinning until the plants are 8 to 10 inches high and have 10 to 12 normal leaves, and by leaving the plants closer together in the row.²

The best spacing distance for the plants has been found to depend somewhat upon local and seasonal conditions. Mr. E. W. Hudson

¹ Hudson, E. W. Growing Egyptian cotton in the Salt River Valley, Arizona. U. S. Dept. Agr., Farmers' Bul. 577, 8 p. 1914.

² These investigations were made by Mr. O. F. Cook and his assistants, and the details, of the investigations, as well as the cultural recommendations resulting from them, have been published in several bulletins and circulars, for the titles of which see the last section of this paper on the literature of the industry.

states that on rich alfalfa land and with irrigation properly managed 6 to 8 inches is about the right distance, while on new land the plants can safely be left 4 inches apart. The thinning should be done in such a way as to result in suppressing practically all of the vegetative branches without stunting the growth of the central stem or shading too much the lower fruiting branches.

This new method of delayed thinning and of closer spacing of the plants has resulted in securing a much earlier development of the crop, as well as in making the picking much easier and cheaper. The time and manner of thinning are so important that they merit the closest personal attention of the grower, the more so as it is impossible to lay down general rules which will be equally well suited to each type of soil and to each season.

UNDESIRABILITY OF RATOONING EGYPTIAN COTTON.

The winters of southern Arizona are often mild enough to allow many of the old cotton stumps to remain alive in the ground, and it is possible to grow a second crop from them. This has suggested the ratooning of Egyptian cotton, a practice which has recently had some advocates in the Salt River Valley. Ratooning was formerly practiced in Egypt, but the system was discontinued in that country because of the poor quality of the fiber produced. The practice has also been thoroughly tested with Durango cotton in the Imperial Valley, where the results were unsatisfactory.

While ratooning saves the labor of spring planting and results in the earlier maturity of the crop, it has no other advantage. A perfect stand can rarely be had, and the seedling plants with which the gaps must be filled ripen later than the ratooned plants and produce fiber of different length and quality, making it impossible to obtain a uniform product from the field. It is questionable whether the very early ripening of the ratooned cotton is really a benefit, since it necessitates picking during the hottest season of the year. It would also be difficult to keep the land from becoming weedy if this method were followed. Finally, the practice of leaving the old stumps in the ground would favor the increase of such injurious insects and fungi as might gain a foothold in the locality. The advisability of replanting the fields each year with the best seed obtainable can not be too strongly urged.

ENEMIES OF THE CROP.

Fortunately no very serious diseases or insect enemies of the crop have yet appeared in the Salt River Valley. A weevil, very closely related to the Mexican cotton boll weevil and capable of feeding upon and depositing its eggs in the bolls of cotton, is native to the mountains of southern Arizona, occurring on a wild plant somewhat

nearly related to the cotton plant.¹ Neither this weevil nor the true Mexican boll weevil has as yet been observed in the cotton fields of the Salt River Valley. An aphid commonly attacks the young plants, and in 1914 it persisted in large numbers until late in the summer, but it has not been shown that this insect causes serious damage to the crop. Bollworms occur in small numbers, but have not thus far been a source of appreciable damage. The dreaded pink bollworm, which has recently played havoc with the cotton crop of Egypt, has fortunately not yet been observed in the United States, and it is to be hoped that the measures taken by the Federal Horticultural Board will prevent its introduction.

Certain fungous diseases, while rather common, do not appear to be severely injurious. The seedling cotton plants are subject to attack, especially when cold weather occurs after planting, by a species of *Rhizoctonia*, causing the disorder known as "sore shin." When this disease is very prevalent, some replanting is likely to be necessary, but the plants which survive soon cease to show any effects of the trouble. Small areas, particularly in old fields which have previously been in alfalfa, are subject to a root rot, or wilt,² which toward the end of the summer causes the cotton to die rapidly in well-defined spots. The percentage of the total acreage thus affected is small, and the disease does not appear to spread rapidly through the soil or to be a serious factor in production when a suitable rotation of crops is followed.

The cotton seedlings are also subject to a disorder known as leaf-cut,³ which is apparently a physiological derangement not associated with a parasitic organism. The symptoms are mutilation of the leaves and sometimes the abortion of the growing point of the stem, resulting in the malformation of the plants most seriously affected. Since the plants are subject to this disorder only while very young, the system of late thinning eliminates its effects by permitting the "chopping" out of the malformed plants.

CONDITIONS OF SUCCESSFUL EGYPTIAN-COTTON PRODUCTION.

The experience gained in connection with the establishment of the community growing of Egyptian cotton in the Salt River Valley makes it possible to formulate the conditions which appear to be indispensable to the successful production of this crop in the United

¹ Cook, O. F. A wild host plant of the boll weevil in Arizona. *In Science*, n. s., v. 37, no. 946, p. 259-261. 1913.

Bailey, Vernon. The wild cotton plant (*Thurberia thespesioides*) in Arizona. *In Bul. Torrey Bot. Club*, v. 41, no. 5, p. 301-306, 2 fig. 1914.

Coad, B. R. Relation of the Arizona wild cotton weevil to cotton planting in the arid West. U. S. Dept. Agr. Bul. 233, 12 p., 4 pl. 1915.

² The identity of this disease has not yet been established.

³ Cook, O. F. Leaf-cut, or tomosis, a disorder of cotton seedlings. *In U. S. Dept. Agr., Bur. Plant Indus. Circ.* 120, p. 29-34, 1 fig. 1913.

States. These are, briefly, (1) a growing season of about nine months, or several weeks longer than is required to mature a full crop of Upland cotton; (2) a reliable supply of water for irrigation; (3) labor sufficient to pick the acreage planted; (4) absence of other types of cotton in the locality, as otherwise pure seed and a uniform fiber can not be maintained; (5) an acreage sufficient to warrant the purchase of roller gins and other equipment and the employment of a competent classer, in order to market the cotton in even-running lots of commercial size; and (6) the cooperative organization of the growers for the purpose of maintaining the seed supply, operating the gins, and marketing the crop.

Communities in which all of the above conditions can not be met are not advised to undertake the growing of Egyptian cotton. In any event, a new community which contemplates the growing of this crop should experiment at first on a small scale and under expert advice, in order to make sure before investing capital in the enterprise that the climatic and soil conditions are favorable to producing large yields and a good quality of fiber.

CONCLUSION.

The history of the establishment of Egyptian-cotton production in the Salt River Valley is believed to have more than a special or local interest, since it offers a good illustration of the numerous biological, agronomic, social, and economic difficulties encountered in developing a new agricultural industry and furnishes suggestions as to how these complex and diversified problems may be successfully solved. That cooperation is the keynote of success has become very clear in the progress of the present enterprise. In this instance cooperation has been maintained along the following lines:

(1) Cooperation among the investigators has brought to the solution of the special problems different equipments of technical training and knowledge and different points of view, while their collective judgment has been focused upon matters of general policy. The cordial and effective cooperation of the administrative officers of the Department of Agriculture has also been an important factor in this connection.

(2) Cooperation among the growers has made it possible to produce and market the crop economically and to maintain the uniformity and high quality of the variety grown.

(3) Cooperation between the growers and the investigators has made it possible to put into effect without delay the most improved methods of production and marketing. This cooperation has been maintained by personal contact, since, in addition to the field agents of the department who have worked constantly in the community,

members of the Committee on Southwestern Cotton Culture have made frequent visits to the Salt River Valley. The attitude of the officers and members of the growers' associations in their cooperation with the Department of Agriculture has been of the most cordial and helpful character, and has been a very important factor in the establishment of the industry.

(4) Cooperation with the cotton manufacturers on the part of both investigators and growers has also contributed largely to the development of the industry. Manufacturers have assisted most willingly and effectively in making spinning tests of the product from time to time, and in furnishing both to the Department of Agriculture and to the growers' associations useful information concerning the cotton. This information has guided the growers to better methods of handling the product, and has given the investigators helpful suggestions in connection with the breeding work. Some of the manufacturers interested in this type of cotton have visited the Salt River Valley in order to learn at first hand the condition and prospects of the industry, while representatives of the growers' associations and of the department have been welcome visitors at mills where the cotton is being utilized.

The policy of the Department of Agriculture in encouraging the production of long-staple cotton on the community basis is beginning to be appreciated by manufacturers and buyers, many of whom now realize that in order to obtain year after year ample quantities of cotton of unchanging character they must look to localities where the farmers are organized to grow only one kind of cotton, to prevent deterioration of the type by seed selection, and to class and market their crop as a unit.

LIST OF PUBLICATIONS BEARING ON EGYPTIAN-COTTON GROWING IN THE SOUTHWESTERN STATES.

The following is a list of publications dealing with the activities of the United States Department of Agriculture in connection with the establishment of Egyptian-cotton growing in the Southwest. Several of the publications listed do not deal directly with Egyptian cotton, but are included because they describe different phases of the investigations which have formed the basis for the establishment of this industry.

Egyptian cotton in the southwestern United States. By Thomas H. Kearney and William A. Peterson. Bureau of Plant Industry Bulletin 128. Issued June 13, 1908.

Suppressed and intensified characters in cotton hybrids. By O. F. Cook. Bureau of Plant Industry Bulletin 147. Issued April 7, 1909.

Experiments with Egyptian cotton in 1908. By Thomas H. Kearney and William A. Peterson. Bureau of Plant Industry Circular 29. Issued April 16, 1909.

A study of diversity in Egyptian cotton. By O. F. Cook, Argyle McLachlan, and R. M. Meade. Bureau of Plant Industry Bulletin 156. Issued July 24, 1909.

Local adjustment of cotton varieties. By O. F. Cook. Bureau of Plant Industry Bulletin 159. Issued September 28, 1909.

Origin of the Hindi cotton. By O. F. Cook. Bureau of Plant Industry Circular 42. Issued December 11, 1909.

Mutative reversions in cotton. By O. F. Cook. Bureau of Plant Industry Circular 53. Issued March 21, 1910.

Cotton selection on the farm by the characters of the stalks, leaves, and bolls. By O. F. Cook. Bureau of Plant Industry Circular 66. Issued August 13, 1910.

Breeding new types of Egyptian cotton. By Thomas H. Kearney. Bureau of Plant Industry Bulletin 200. Issued December 23, 1910.

Dimorphic branches in tropical crop plants: Cotton, coffee, cacao, the Central American rubber tree, and the banana. By O. F. Cook. Bureau of Plant Industry Bulletin 198. Issued January 14, 1911.

Hindi cotton in Egypt. By O. F. Cook. Bureau of Plant Industry Bulletin 210. Issued May 11, 1911.

Arrangement of parts in the cotton plant. By O. F. Cook and R. M. Meade. Bureau of Plant Industry Bulletin 222. Issued October 3, 1911.

Dimorphic leaves of cotton and allied plants in relation to heredity. By O. F. Cook. Bureau of Plant Industry Bulletin 221. Issued November 22, 1911.

Cotton improvement on a community basis. By O. F. Cook. Yearbook, U. S. Dept. of Agriculture, for 1911, pp. 397-410.

Suggestions on growing Egyptian cotton in the Southwest. By Carl S. Scofield. Bureau of Plant Industry Document 717. Issued January 9, 1912.

Results of cotton experiments in 1911. By O. F. Cook. Bureau of Plant Industry Circular 96. Issued July 17, 1912.

The branching habits of Egyptian cotton. By Argyle McLachlan. Bureau of Plant Industry Bulletin 249. Issued September 20, 1912.

Improved methods of handling and marketing cotton. By Charles J. Brand. Yearbook, U. S. Dept. of Agriculture, for 1912, pp. 443-462.

Morphology of cotton branches. By O. F. Cook. Bureau of Plant Industry Circular 109, pp. 11-16. Issued January 4, 1913.

Heredity and cotton breeding. By O. F. Cook. Bureau of Plant Industry Bulletin 256. Issued January 13, 1913.

Preparation of land for Egyptian cotton in the Salt River Valley, Arizona. By E. W. Hudson. Bureau of Plant Industry Circular 110, pp. 17-20. Issued January 18, 1913.

Fiber from different pickings of Egyptian cotton. By Thomas H. Kearney. Bureau of Plant Industry Circular 110, pp. 37-39. Issued January 18, 1913.

Egyptian cotton as affected by soil variations. By Thomas H. Kearney. Bureau of Plant Industry Circular 112, pp. 17-24. Issued February 8, 1913.

A wild host plant of the boll weevil in Arizona. By O. F. Cook. Science, n. s., v. 37, pp. 259-261. Issued February 14, 1913.

A new system of cotton culture. By O. F. Cook. Bureau of Plant Industry Circular 115, pp. 15-22. Issued March 1, 1913.

The fundamentals of crop improvement. By W. T. Swingle. Bureau of Plant Industry Circular 116, pp. 3-10. Issued March 8, 1913.

The abortion of fruiting branches in cotton. By O. F. Cook. Bureau of Plant Industry Circular 118, pp. 11-16. Issued March 22, 1913.

Leaf-cut, or tomosis, a disorder of cotton seedlings. By O. F. Cook. Bureau of Plant Industry Circular 120, pp. 29-34. Issued April 5, 1913.

Factors affecting the production of long-staple cotton. By O. F. Cook, Bureau of Plant Industry Circular 123, pp. 3-9. Issued April 26, 1913.

Egyptian cotton culture in the Southwest. By Carl S. Scofield. Bureau of Plant Industry Circular 123, pp. 21-28. Issued April 26, 1913.

Agriculture on the Yuma Reclamation Project. By Carl S. Scofield. Bureau of Plant Industry Circular 124, pp. 3-8. Issued May 3, 1913.

Cotton farming in the Southwest. By O. F. Cook. Bureau of Plant Industry Circular 132, pp. 9-18. Issued July 19, 1913.

Seed selection of Egyptian cotton. By Thomas H. Kearney. U. S. Dept. of Agriculture Bulletin 38. Issued November 19, 1913.

Cotton as a crop for the Yuma Reclamation Project. By the Committee on Southwestern Cotton Culture. Bureau of Plant Industry Document 1009. Issued December 1, 1913.

The relation of cotton buying to cotton growing. By O. F. Cook. U. S. Dept. of Agriculture Bulletin 60. Issued February 16, 1914.

Growing Egyptian cotton in the Salt River Valley, Arizona. By E. W. Hudson. U. S. Dept. of Agriculture, Farmers' Bulletin 577. Issued March 14, 1914.

Mutation in Egyptian cotton. By Thomas H. Kearney. U. S. Dept. of Agriculture, Journal of Agricultural Research, v. 2, no. 4, pp. 287-302. Issued July 15, 1914.

The wild cotton plant (*Thurberia thespesioides*) in Arizona. By Vernon Bailey. Bulletin, Torrey Botanical Club, v. 41, pp. 301-306. Issued May 29, 1914.

Single-stalk cotton culture. By O. F. Cook. Bureau of Plant Industry Document 1130. Issued December 14, 1914.

Relation of the Arizona wild cotton weevil to cotton planting in the arid West. By B. R. Coad. U. S. Dept. of Agriculture Bulletin 233. Issued May 27, 1915.

Single-stalk cotton culture at San Antonio. By Rowland M. Meade. U. S. Dept. of Agriculture Bulletin 279. Issued August 24, 1915.

Custom ginning as a factor in cotton-seed deterioration. By D. A. Saunders and P. V. Cardón. U. S. Dept. of Agriculture Bulletin 288. Issued September 7, 1915.

The handling and marketing of the Arizona-Egyptian cotton of the Salt River Valley. By J. G. Martin. U. S. Dept. of Agriculture Bulletin 311. Issued November 26, 1915.

Community production of Durango cotton in the Imperial Valley. U. S. Dept. of Agriculture Bulletin 324.

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BULLETIN No. 333

Contribution from the Bureau of Entomology
L. O. HOWARD, Chief



Washington, D. C.

PROFESSIONAL PAPER

February 16, 1916

TERMITES, OR "WHITE ANTS," IN THE UNITED STATES:
THEIR DAMAGE, AND METHODS OF PREVENTION.¹

By THOMAS E. SNYDER, M. F.,
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INTRODUCTION.

Termites, or "white ants," which are classed among the most injurious insects to man's industry in tropical regions, are by no means restricted to the Tropics and in the United States are capable of seriously damaging the woodwork as well as the contents of buildings and other structures of wood, and occasionally the roots of living trees and various growing crops. In the United States these insects more frequently occur and more often become a pest in the Southern States. Due to their subterranean habits, insidious method of attack, and often countless numbers, termites are very difficult to destroy. Always coming up through underground galleries, they work under cover, avoiding exposure to the light, so that the damage is often hidden until beyond repair.

CLASSIFICATION.

"White ants" are not ants, but, because of their superficial resemblance to ants (except in color) and their communal habits, they have been almost universally so termed. Thus these insects, since they live

¹ The species principally treated herein are *Leucotermes flavipes* Kollar, *L. virginicus* Banks, and *L. lucifugus* Rossi.

in colonies which are made up of various highly specialized forms or castes, are naturally to be classed among the so-called social insects, comprising the ants, bees, and wasps. Each of these forms has a duty in this organization and there is a division of labor. In the systematic classification of insects, however, termites are widely separated from the other social insects, which represent the highest and most specialized development, while termites are among the lowest and oldest insects. Further, in many points in their life habits termites differ widely from the other social insects.

DESCRIPTION OF THE INSECTS.

THE DIFFERENT FORMS OR CASTES IN THE COLONY.

Since the work of termites is largely subterranean, or under cover, the insects are rarely observed at work and the injury is often hidden

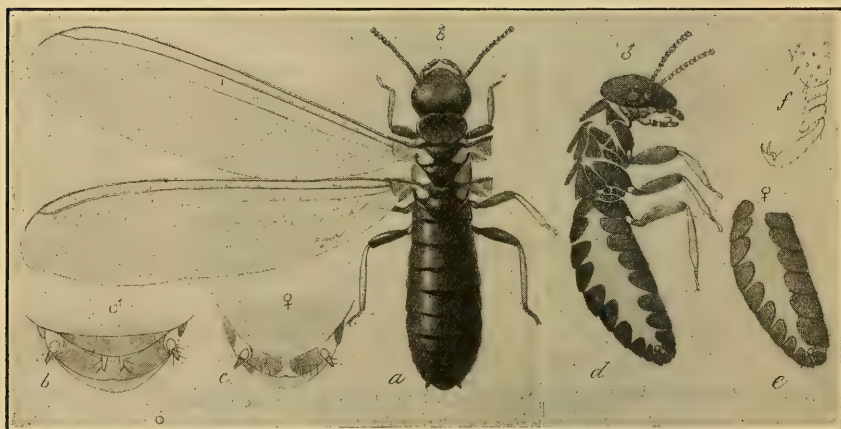


FIG. 1.—*Leucotermes flavipes*: *a*, Adult male; *b*, terminal abdominal segments from below; *c*, same of female; *d*, male, side view, somewhat inflated by treatment with ammonia; *e*, abdomen of female, side view; *f*, tarsus, showing joints and claws. *a*, *d*, *e*, Enlarged; *b*, *c*, *f*, greatly enlarged. (After Marlatt.)

until the destruction of the wood that they are inhabiting is complete. An indication of the presence of termites is the annual flight or swarm of the winged colonizing sexed adults which emerge in enormous numbers from the ground and crevices or holes in infested wood.

In the communal societies of termites, however, there are both wingless and winged mature individuals, as well as the young of the different forms in various stages of development. The brownish or blackish, elongate, slender, antlike adults (fig. 1) with long white wings are not the most destructive form, although they have biting mouthparts, but are migratory individuals which have the sexual organs developed, and appear normally only once a year during a certain season, which varies with the species. These male and female

reproductive forms have functional eyes, and, unlike the other forms, are especially adapted to endure full sunlight, since it is necessary that they come above ground to found new colonies, possibly because of a superabundance of life in the old, parent colony, or in order that the species may become more widely disseminated.

The dirty-white, soft-bodied, large-headed, wingless "workers" (Pl. I, fig. 1) comprise the most destructive form. These "workers" have varied and important duties; they make the excavations, enlarge and extend the colony as this becomes necessary, and care for and protect the young and reproductive forms. The soft-bodied, wingless "soldiers" (Pl. I, fig. 2), which have an elongate narrow head armed with long, slender, saber-shaped jaws, and the workers are the most numerous forms permanently present in the colony. The duty of the specially developed soldiers is apparently protective. Both the workers and soldiers consist of individuals of either sex, but the sexual organs remain undeveloped. The integument of the body of these insects is delicate and the chitinous plates are never very hard. These forms are blind and rarely appear above ground; hence in all their operations they carefully shun the light, which they nevertheless are apparently able to detect. Other forms are the reproductive individuals, which may be either a single pair, the normal king and queen (Pl. II, figs. 1 and 2), or in other colonies many supplementary forms of nymphal types (Pl. II, figs. 3 and 4; text fig. 4, *b*) or larval types (fig. 3; fig. 4, *c*).

THE DIFFERENT SPECIES OF TERMITES.

Of the many different species of termites in North America, the habits of only three are here considered in detail, namely, the common native termite (*Leucotermes flavipes* Kollar), a European termite (*Leucotermes lucifugus* Rossi), and the native southern species (*Leucotermes virginicus* Banks). These termites are greatly similar in form and habit and are all wood-destroying species of subterranean habits, with a relatively northern distribution. The winged sexed adults have strongly reticulated wings.¹

In case of *flavipes* ("yellow foot"), these adults are clear castaneous-brown, 9 to 10 mm.² in length, including the wings, which are dull white in color, or plainly darkened, the borders being clear brownish, except at the base. The simple eyes or ocelli are separated from the faceted compound eyes by the width of their diameter. The swarm is usually in April or May. The soldiers are 6 to 7 mm. in length, the head being about once and two-thirds as long as broad.

In *lucifugus* ("light shunning"), the winged adults are dark blackish-brown, 11 to 12 mm. in length including the wings, the latter being dull smoky blackish with the borders black-brown. The ocelli are nearer to the compound eyes. This species swarms from October to April.

The southern smaller species (*virginicus*) is yellowish brown in color, being 7.5 to 8 mm. in length, including the wings, which are not darkened. The

¹ Subgenus *Reticulitermes* Holmgren.

² 1 mm.=one twenty-fifth inch.

swarm is usually in early June or later in the summer. The soldier is more slender than in *flavipes*, 4.5 to 5 mm. in length, the head being twice as long as broad.

In certain localities where several species of termites are known to occur the injury herein described can not always be attributed to a definite species, since specimens of the insects were sometimes not taken. This is particularly the case in the Southwestern and Gulf States and on the Pacific coast. It is probable that species not previously recorded as injurious will be found to be injurious, and it is known that undescribed species or those new to science occur.

COMMUNAL ORGANIZATION AND LIFE.

SITUATION OF THE COLONIES OR NESTS.

In North America termites do not construct large permanent nests of earth or mounds above ground, as in the Tropics. They make the nests in the wood of dead trees, decaying logs, or stumps in the forest; or in the foundation timbers of buildings, fences, or other structures of wood in contact with the ground; or in a labyrinth of underground passages in the earth, usually underneath wood or other vegetation. These nests are not as permanent as the mound nests, since the species have wandering habits and there are seasonal changes in the colony life. These species of termites (*Leucotermes* spp.) are essentially wood destroyers; their excavations usually follow the grain in solid wood. A protective outer shell of wood is always left intact by these blind, soft-bodied insects. Termites infest buildings by means of tunnels through the ground to and up through the foundation timbers, or, in case of foundations of stone or other impenetrable material, cover their pathway by means of "sheds" constructed of earth and excrement over the surface to the woodwork. Termites sometimes inhabit and enlarge the burrows of various other wood-boring insects.

SEASONAL VARIATIONS IN THE COLONY.

The center of activity in termite colonies changes with the seasons, due to varying needs as to conditions of warmth and moisture. In the eastern United States, in spring, when there is abundant moisture, outlying galleries of colonies are teeming with life, where, during the heat of summer, conditions would be too dry. In arid regions termites burrow deep into the ground; consequently in summer they bury themselves more deeply, going into the less exposed galleries. In the late autumn or at the beginning of winter (in northern Virginia, late October or early November) they enter the ground and do not come above ground till late in February or early March. Again, the colony readily migrates and the site is abandoned if conditions



FIG. 1.—Mature “workers” of *Leucotermes flavipes*; chloroformed, living insects. Enlarged three times. (Original.)



FIG. 2.—Mature “soldiers” of *Leucotermes flavipes*; chloroformed, living insects. Enlarged three times. (Original.)

TERMITES, WORKERS AND SOLDIERS.



FIG. 1.—Mature "king" of normal form, several years of age. Etherized specimen, enlarged six times. (Original.)



FIG. 2.—True "queen" with wing stubs and castaneous pigmentation to chitinized parts. Enlarged six times. (Original.)



FIG. 3.—Neoteinic nymphal "king" showing tapering abdomen and characteristic pubescence. Enlarged seven times. Alcoholic specimen. (Original.)



FIG. 4.—Neoteinic nymphal "queen" with straw-colored pigmentation to chitinized parts. Enlarged seven times. (Original.)

become unfavorable. A single colony may be spread over an extensive area, and it is often impossible to define the limits of a colony. At higher altitudes in the Appalachian Mountains, in the canyons of the Southwest, and in high mountains in the West, termite colonies in the earth and under stones are more common. Colonies of *Eutermes* are commonly found in the earth.

NUMBER OF INDIVIDUALS IN COLONIES.

Average colonies probably contain several thousand individuals. In old, long-established termite colonies the number of individuals runs up into the tens of thousands. Young, recently established or incipient colonies are small and the increase in numbers is slow.

THE LIFE CYCLE.

THE METAMORPHOSIS AND CASTE DIFFERENTIATION.

The recently hatched termite larvæ (fig. 2) are all similar or undifferentiated, but are active from the first. At a later molt two types, large and small headed larvæ, can be distinguished. The former, after a series of molts and quiescent stages of comparatively short duration, develop to workers and soldiers, the latter to reproductive forms.

There is no apparent or external change in the development of the worker, the larva being active and of the same form as the adult. There are marked changes, however, in the development of the soldier, with narrow, elongate head and saberlike jaws, from the round-headed worker-like larva. The winged, pigmented, sexed adults and the several types of neoteinic reproductive forms are developed from small-headed larvæ, there being still more radical changes, the former originating from nymphs of the "first form," with long wing pads, the latter from nymphs of the "second form" (Lespès) with short wing pads, or from young larvæ.

However, in all stages of the development of termites, what may be termed the "antlike" form of all castes can be recognized. There are no long inactive larval and pupal stages as in the ants and other social insects.

In the life cycle of termites there is so much variation in the development of the castes that there is consequently a rather complex



FIG. 2.—*Leucotermes flavipes*: a, Newly hatched larva; b, same from below; c, egg. All enlarged. (From Marlatt.)

life history. Young are kept in a retarded, undifferentiated state and can be rapidly turned into supplementary or substitute reproductive forms of both sexes.

THE SEVERAL TYPES OF REPRODUCTIVE FORMS.

The nymphs of the first form, with long wing pads, develop to the winged sexed adults, which, after the swarm, lose the wings and become the kings and queens of the normal reproductive form. These normal kings and queens are blackish or brown in color, have eyes, and retain the stumps of their discarded wings (fig. 4, *a*).

From the nymphs of the second form, with short wing pads, are developed, probably by the workers, individuals of the substitute nymphal reproductive form of both sexes (Pl. II, figs. 3 and 4; text fig. 4, *b*). These nymphs of the second form are merely nymphs of the first form whose usual development to the pigmented, winged, sexed adults is retarded at a certain stage and never completed; the insects, instead, acquiring a pale yellowish or grayish color and becoming

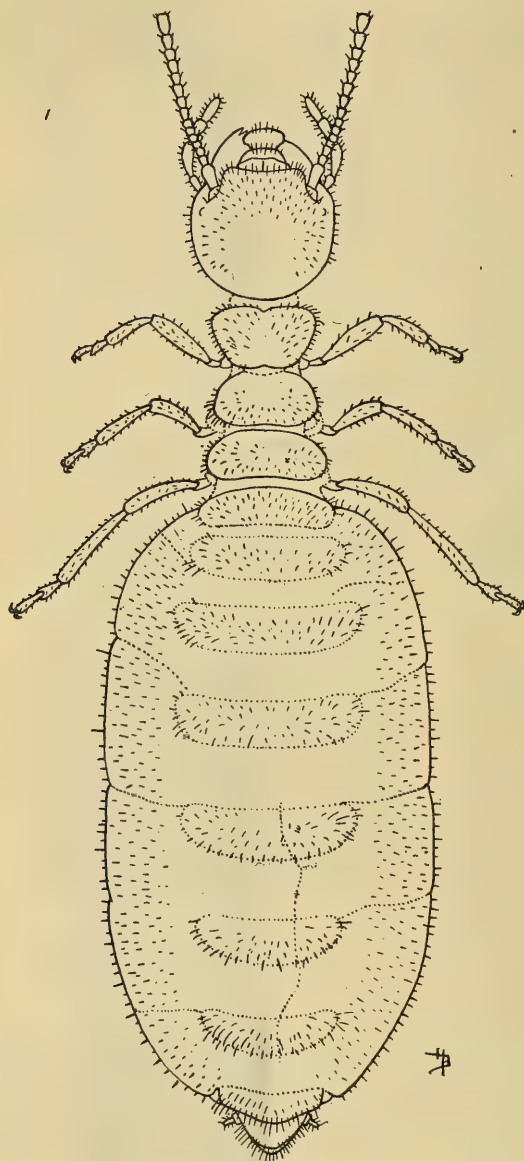


FIG. 3.—*Leucotermes flavipes*: Larval, worker-like reproductive form ("ergatoid queen," 9 mm. in length, alcoholic specimen). (Original.)

sexually mature normally after the sexed adults have swarmed. Individuals of this neoteinic reproductive form are apparently blind, not being destined to leave the parent colony, unless by underground tunnels.

Another type of substitute or neoteinic reproductive form, which greatly resembles the worker ("ergatoid"), is developed from young larvæ of the sexed forms. Of a pale yellowish or grayish color and having no wing pads (fig. 3; fig. 4, *c*), individuals of this larval supplementary reproductive form are apparently blind and never leave the parent colony, unless by underground tunnels.

In neither of the types of supplementary reproductive forms do the queens become as large as the normal queens, but there are usually many present in the same colony, as well as several males, or kings. The largest queen found in the United States of *L. flavipes* Kol. is only 14½ mm. in length and 4 mm. in width (measured while liv-

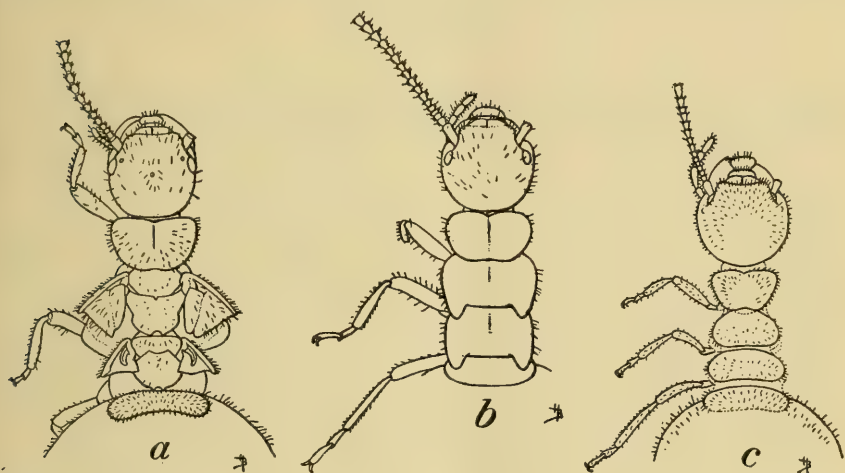


FIG. 4.—*Leucotermes flavipes*: Details of head and thorax of the three forms of reproductive females. *a*, True queen, or adult form, 14.5 mm. in length, wing stubs present; *b*, supplementary or "neoteinic" queen, or nymphal form, 9 mm. in length, wing pads present; *c*, worker-like or "ergatoid" queen, or larval form, 9 mm. in length, without wing pads. (Original.)

ing)—a queen of the normal type with wing stubs. Nymphal neoteinic queens 12 mm. in length (alcoholic specimens) and larval neoteinic queens 7 mm. in length (measured while living) are the largest that have been found of this species. The abdomens of nymphal queens are often distorted by the development of the ovaries and present an irregular, lopsided outline. These neoteinic forms of both sexes are probably developed to take the place of the normal forms in case of loss or possibly in the establishment of branch colonies; i. e., they may be impelled to migrate from overstocked colonies by means of underground passages. Queens of all these different types of reproductive forms are active even after the abdomen has become greatly distended.

DURATION OF DEVELOPMENT AND LIFE.

The workers, like the soldiers, complete their development in less than a year. The development of the nymphs of the reproductive forms (coming from larvæ that will mature the sexual organs) apparently requires two seasons.

For the development of the queen of the normal type to the maximum size several years are required.

There are no data on the length of life of individuals of the various castes, but the king and queen probably continue to live together for many years, under normal conditions, since they are of equal importance to the community.

THE SWARM.

At a certain season of the year the colonizing, winged, sexed individuals are impelled to migrate from the parent colonies in decaying logs, stumps, woodwork in buildings, etc. In case of the widely distributed species *flavipes*, the colonizing forms emerge from colonies in April or early in May in the Southern States or the last of May or early June in the Northern States; the swarm usually occurs in the morning or in the middle of the day, in case of large colonies usually lasting about two hours. The southern species *virginicus* swarms in early June, but sometimes as late as the first part of August in northern Virginia; while the species *lucifugus* of Mediterranean Europe swarms from the middle of October to April in Texas, Kansas, Colorado, and on the Pacific coast, usually after showers. Often several swarms occur from the same colony, extending over a period of four weeks. In colonies in infested buildings the winged males and females usually emerge about one month before the swarm occurs outdoors.

THE FOUNDATION OF NEW COLONIES.

After the adults have rapidly emerged from the parent colony, from crevices in the infested wood, in a swarm of enormous numbers and have flown a short distance in an irregular, "wobbly" manner, they fall to the ground. The flight is usually not farther than from 75 to 100 feet, but the insects, usually flying low, are sometimes carried farther by the wind. Both during and after the flight they are promptly preyed upon and destroyed by many insectivorous animals which are attracted to the cloud of flying insects, resulting in an enormous mortality.

Among these enemies are many species of wild birds which are attracted to swarms of termites in woodland and greedily capture the flying insects in midair.

Hagen states,¹ in mentioning an exceptionally large swarm which occurred in Massachusetts:

Last Sunday, May 19 (1878), on North Avenue, near Everett Street, there passed just before the windows of the house of Prof. Hedge, while the family was at breakfast, a cloud of flying insects, dark enough to draw the attention of the family. They went out of doors and saw the cloud coming from the east, a part alighting on the garden steps. Some of the insects were preserved alive and sent to me, and proved to be *Leucotermes* (*Termes*) *flavipes*.

The phenomenon was more remarkable, and their attention more strongly called to it, by finding 15 different kinds of birds following the insects so eagerly that even the presence of the family did not disturb them. Besides the common robins, bluebirds, and sparrows, were others not seen before near the house. The birds caught the *Termes* partly in flight, partly on the ground, and the robins were finally so gorged in appearance that their bills stood open.

I think such a flock of birds following an emigration of white ants—which is very common in the Tropics—has never been noticed here. Perhaps the very early appearance of white ants (commonly they arrive in the middle of June) explains the hunger and eager persecution of the birds, as other insects are still rare.

The Biological Survey has found that termites constitute part of the food of at least 27 of the species of birds living in the United States. The woodpeckers are represented in this list by 8 species, and no fewer than 1,100 termites have been found in a single stomach of the common flicker. Other birds consuming noteworthy numbers of termites are the nighthawk (largest number found in one stomach, 220), chimney swift (160), tree swallow (75), barn swallow (50), and bank swallow (50). The complete list of birds is as follows: Wood duck, hairy woodpecker, downy woodpecker, red-cockaded woodpecker, Nuttall's woodpecker, pileated woodpecker, flicker, red-shafted flicker, gilded flicker, nighthawk, chimney swift, kingbird, Cassin's kingbird, black phoebe, western wood-pewee, horned lark, meadowlark, song sparrow, scarlet tanager, barn swallow, tree swallow, bank swallow, mockingbird, catbird, Carolina wren, wood thrush, and bluebird.

Barnyard fowls also are attracted to the swarming insects and capture large quantities of the insects as they emerge. Lizards (in California and in southeastern Texas) have been observed to devour swarming termites. Many different species of spiders also prey on the insects after they alight on the ground. Among the insects, ants² greatly diminish the number of the colonizing individuals at the time of the annual swarm. Centipedes have been observed in Virginia to carry away in their mandibles workers from a disorganized colony; they are sometimes found in the covered earthen runways of termites. Crickets³ have been recorded feeding

¹ Hagen, H. A. Note.—*In* Proc. Soc. Nat. Hist. Boston, v. 20, p. 118, Nov. 27, 1878.

² Species of *Cremastogaster*, *Camponotus*, and *Formica*.

³ *Gryllus pennsylvanicus* Burm.

on swarming adults (*lucifugus*) in Kansas (McCulloch). Probably there are many other insectivorous animals that reduce the enormous number of winged termites.

While clumsy in flight, termites are able to run rapidly, but apparently never wander great distances. Further, even some of those pairs that escape being devoured fail to become established in new colonies because of unfavorable moisture conditions in the incipient colony.

The male is attracted to the female, and after the flight, either before or after the now useless and retarding wings have been discarded by being pried off at a suture near the base, tirelessly and closely follows her about. In this manner the insects separate into pairs and become established in shallow cells in the earth, usually under decaying pieces of wood, in holes in the wood, or under moist bark, thus independently establishing new colonies.

The female in seeking the site of the new colony is sometimes followed by more than one male, and in shallow cells excavated by these reproductive forms there may be one female associated with two males or vice versa.

MATING.

During the first stages of colonization both the male and female are active, forage for themselves, and are apparently equally important in the establishment of the new colony and the independent rearing of the first brood of young.

The habitation of the male and female or incipient colony is called the "royal cell," since it is occupied by a single parent pair, the especially developed "king and queen," which have originated from the winged, sexed adults after the swarm. The first brood is reared within the confines of this small chamber. In this type of reproductive form, after the pair have become established together, there is further sexual development and the abdomens of both sexes increase slightly in size. In case of the queen there is a later considerable post-adult growth.

Unlike the other social insects, the sexual relations of the male and female termite are continued. Copulation probably does not take place until about one week after the swarm and the establishment of the pair in the royal cell, but is repeated at irregular intervals over a period of many years.

THE RATE OF EGG LAYING.

Egg laying in newly established colonies in case of the species *flavipes*, in the southeastern United States, begins about the middle of June or July; and in late June to July, or August—unhatched eggs being present till the middle of August—in incipient colonies of

virginicus, varying with the season, or about one and one-half months after the swarming. Usually only 6 to 12 eggs compose the first batch; they are deposited in a cluster in the royal cell and are carefully tended. The eggs begin to hatch in about 10 days after they are laid.

Most larvæ of the first brood develop to workers and a few to soldiers. While the recently hatched young are active they are dependent on the care of the parents for food. During the development of the first brood the male continues to share the cell with the female and both are active. The abdomen of the queen at this time is not markedly distended. Egg laying ceases after the first batch is laid and is not resumed until the first brood of young is mature, i. e., about six months after the first eggs were laid. Copulation and egg laying occur at shorter intervals and more frequently from now on and the abdomen of the queen gradually enlarges, eventually becoming greatly distended through constant care and feeding by the workers and the enormous development of the ovaries. These queens never reach the size attained by species in the Tropics.

The rate of egg laying and development of the young and active queen of this normal type is slow and the new colony is small. Even after the rearing of the first brood the increase in numbers is not rapid. The capacity for egg laying becomes gradually increased as the abdomen enlarges, but queens of these species (*Leucotermes*) never entirely lose the power of locomotion. An isolated, fully developed queen of *flavipes* (approximately 14 mm. in length) was capable of laying, after capture, over 1 dozen eggs between 5 p. m. and 9 a. m. Hence even in large, well-established colonies the rate of egg laying of normal queens is not remarkable. However, where there are many neotenic reproductive forms of both sexes in colonies the increase is rapid and extensive. The rate of egg laying is not comparable to that in tropical species.

Since no types of the reproductive forms ever entirely lose the power of locomotion, there is, in consequence, no permanent royal cell, but these forms are usually in a cell in the more solid wood. In winter they probably are to be found below the frost line in the ground, where termites pass the cold season in a labyrinth of galleries. Wood-boring ants¹ are to be found in frozen masses in galleries in wood, but the soft-bodied termites pass the winter below ground in a state of sluggish activity or are more or less dormant.

THE PERIOD OF MAXIMUM EGG PRODUCTION.

In large, long-established colonies of *flavipes* in the eastern United States eggs and newly hatched larvæ (fig. 2) are to be found

¹*Cremastogaster* sp. and *Camponotus* sp.

from April to October; in incipient colonies of *flavipes* in northern Virginia the first eggs are laid by the middle of June or July, or from the last of June to July or August in case of *virginicus*.

In northern Virginia, in well-established colonies, the period of maximum egg production of both species is from the middle of May to early September; that is, during the warm months.

In infested buildings occupied by man termites are able to maintain their activity during the entire year, and it is probable that eggs are produced in every month of the year.

The eggs are tended by the young parent adults in the royal cell in incipient colonies, but in long-established colonies the eggs are removed by the workers and deposited in clusters in the outlying galleries of the colony where conditions are best suited for rapid hatching.

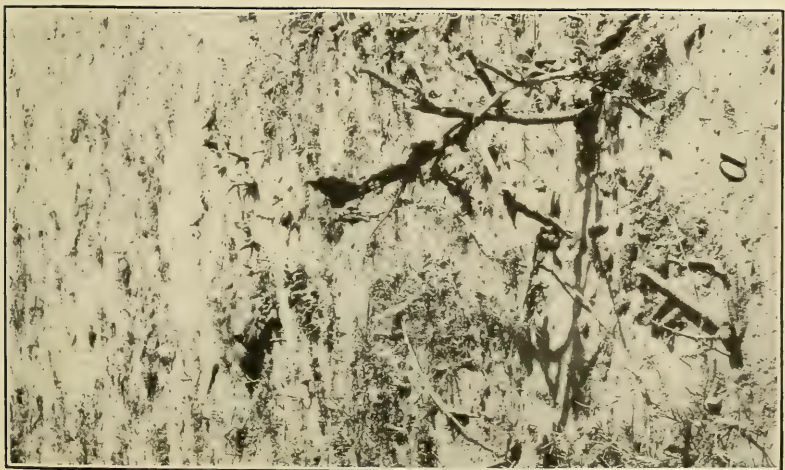
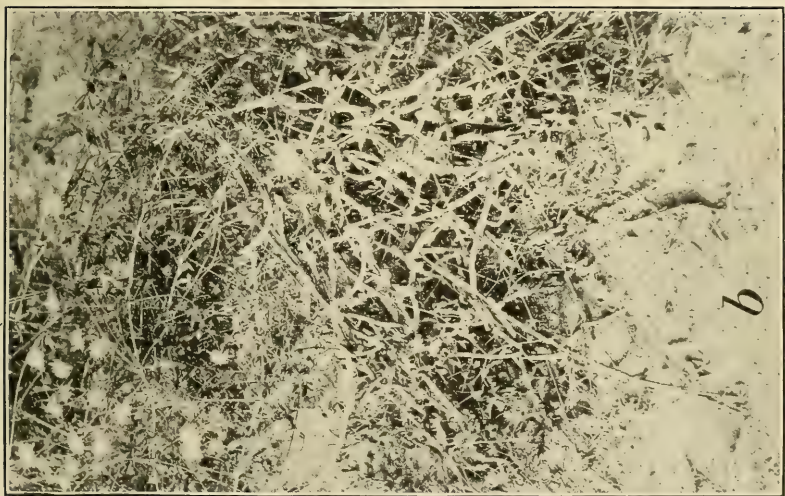
GEOGRAPHICAL DISTRIBUTION.

Termites are widely distributed over the world, but increase in numbers as the Tropics are approached. There are many species in North America. Our common species *flavipes*, according to Marlatt, is very widespread over North America, "occurring from the Atlantic to the Pacific and from Canada southward to the Gulf. It has been found on the mountains of Colorado and Washington at a height of over 7,000 feet." This termite has been introduced into Europe, being also reported to occur in Japan. S. Hozawa states¹ that *Leucotermes spretus* Kolbe is the only representative of the genus *Leucotermes* in Japan, and that *L. flavipes* has not been found in Japan. Another termite closely allied to *flavipes*, *lucifugus*, occurring in the Mediterranean countries of Europe and also in western France and Hungary, but being especially abundant throughout southeastern Europe, according to E. A. Schwarz, originated in Mexico. This insect has also been introduced into North America (western United States). In the United States *lucifugus* is found in Texas, Arizona, Kansas, Colorado, and southern California, and probably occurs elsewhere. This species also occurs at high altitudes in Colorado, i. e., about 6,000 feet. The native species *virginicus* is recorded from the District of Columbia, Maryland, and Virginia, but probably has a wider distribution.

In the prairie regions of Texas and Arizona a tube-forming termite² lives in the ground, in pasture tracts, feeding on the roots of grass and other vegetation, often being found under and within dry cow dung and under stones. A characteristic habit of this grass-destroying species is to cover the stems and roots of vegetation with

¹ Jour. of the College of Science, Tokyo Imperial Univ., v. 35, art. 7, p. 82, Apr. 30, 1915, "Revision of the Japanese Termites."

² *Hamitermes tubiformans* Buckley.



TERMITE SHELTER TUBES.

Stems of both living and dead vegetation incrustated with earthen tubes of the termite, *Hamitermes tubiformans*.
Photographs by H. S. Barber. (Original.)

Esperanza Ranch, Brownsville, Tex., June 12, 1904.

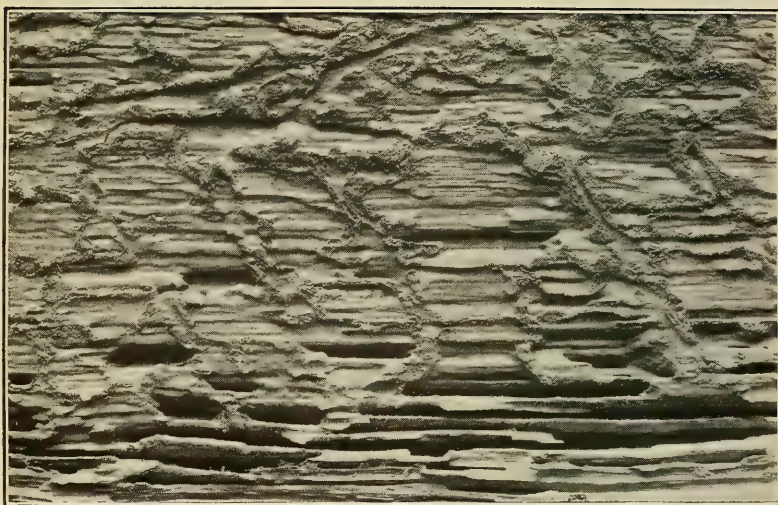


FIG. 2.—Damage by termites (*Leucodermes* sp.) to sound dry red-oak molding from door casing, showing walls of runways coated with earth mixed with finely digested wood. (Original.)

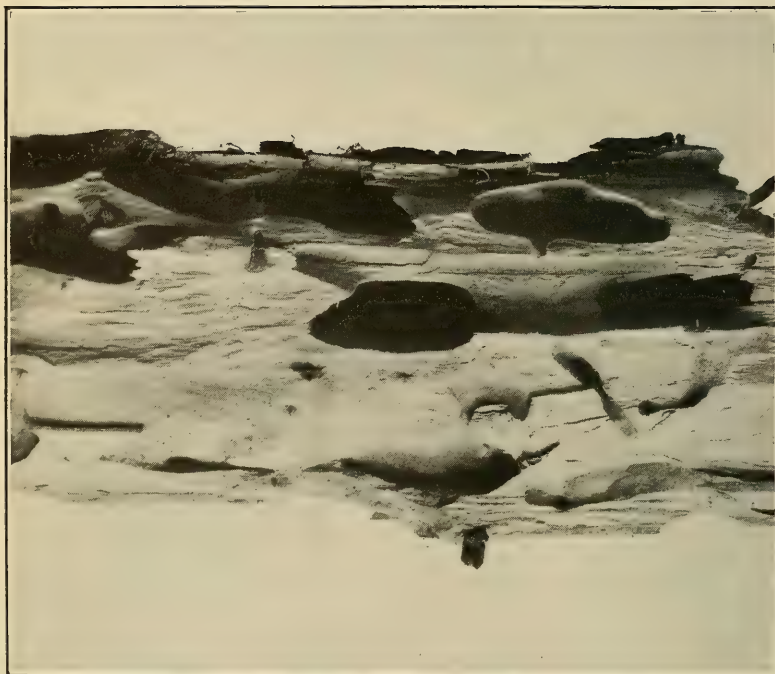


FIG. 1.—Chambers excavated in Arizona cypress (*Cupressus arizonica*) by *Calodermes* sp. Catalina Mountains, Ariz. (Original.)

tubes of small diameter, constructed of earth and excrement (Pl. III). M. Chrisman has found these termites in Arizona under similar coverings at the base of mesquite stumps, fallen limbs, twigs, etc.; always on the dry wood, but not in cells in the wood, apparently eating only the outside. Many other termites occur in North and Central America.

ECONOMIC IMPORTANCE OF TERMITES IN THE UNITED STATES.

While termites damage a great variety of wooden structures, stored books, documents, paper, and other material, as well as occasionally injuring or killing living trees, shrubs, and growing crops, the principal and most serious damage is to foundation timbers and the woodwork of buildings occupied by man and the contents or material stored therein. Similar damage to other construction timber in contact with the ground is considerable in the Southern States. Apparently, it is only occasionally that these insects attack living trees and shrubs, growing crops, or other vegetation, and then only because the land has been recently cleared and there is much decaying wood or humus in the soil; or, according to C. L. Marlatt, of the Bureau of Entomology, in the case of corn in the prairie region of Kansas, because the insects are present in enormous numbers and have been breeding in the heavily sodded soil, where they feed on the roots of the vegetation. Sometimes this injury to growing corn is due also to the method of plowing under old stubble.

Hence, in the following account of general damage to a great variety of stored material and products, as well as living crops, it should be borne in mind that such damage is usually occasional, and then only local and not in general a serious problem.

DAMAGE TO BUILDINGS AND OTHER STRUCTURES OF WOOD.

Damage to foundation timbers, flooring in basements, and other woodwork of dwellings occupied by man, as well as to other buildings, is common and occasionally serious in the eastern and southern portions of the United States, especially in the South Atlantic and Gulf States. Injury of this type has been recorded as occurring in large cities,¹ as well as in rural regions, as far north as Manchester, N. H., and the shores of the Great Lakes (Benton Harbor, Mich.).

¹ Records in the correspondence files of the Bureau of Entomology and branch of Forest Insect Investigations include Benton Harbor, Mich., Manchester, N. H., Boston, Mass., New York, N. Y., Atlantic City, N. J., Philadelphia, Pa., Wilmington, Del., Baltimore, Md., Washington, D. C., Wheeling, W. Va., Cleveland, Cincinnati, and Dayton, Ohio, Indianapolis, Jeffersonville, and South Bend, Ind., Cazenovia, Ill., St. Louis, Mo., Charlotte, N. C., Charleston and Spartanburg, S. C., Louisville and Franklin, Ky., Memphis, Tenn., Augusta and Savannah, Ga., Montgomery and Birmingham, Ala., Vicksburg, Miss., Jacksonville, Miami, and St. Augustine, Fla., New Orleans and New Iberia, La., Beaumont, Dallas, and San Diego, Tex., Little Rock and Van Buren, Ark., Oklahoma City and Wewoka, Okla., Manhattan, Kans., Colorado Springs, Colo., Salt Lake City, Utah, and localities in southern California.

W. D. Hunter stated on November 6, 1915: "The recent hurricane injured practically every building in the city [New Orleans, La.] more or less, and hundreds were completely demolished. * * * Many of the exposed beams were mined by insects and in many cases at least this weakening of the timbers was an important contributory cause of the loss." Much of this damage was probably due to termites.

Termites usually gain entrance to buildings from colonies outdoors, and since the workers can extend subterranean galleries for comparatively long distances, it is often impossible to trace the insects to the outside source. However, these galleries, constructed in search of moist or decaying wood, originate in decaying stumps, poles, fence posts, boards, or other decaying wood, or in the earth not very far away.

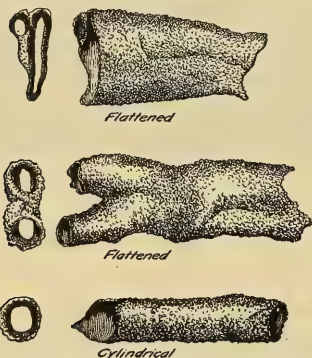


FIG. 5.—Suspended tubes constructed by termites (*Leucotermes flavipes*) of earth and excreted wood, Elkins, Va. Natural size. Drawn by Miss E. Hart. (Author's illustration.)

By means of these subterranean tunnels infestation by way of wooden beams, joists, or supports of porching or steps in contact with the ground is effected. Termites can even pass over impenetrable surfaces, such as stone, brick, or concrete foundations, by means of small sheds or tubes constructed of earth and excrement on such surfaces or by means of suspended tubes (fig. 5). Sometimes ingress is gained through cracks in concrete where foundation timbers are imbedded in this material.

These insects have even been recorded by Forbes as boring several feet through the mortar or cement between the stones in foundation walls and brick partitions of the Statehouse at Springfield, Ill., and by Grant as perforating the mortar of the brick walls of a Missouri Pacific Railroad engine house (probably through cracks or where the cement was disintegrated). There are several records of termites piercing the lead covering to telephone cables in Australia and the United States (Savannah, Ga.).

Since their work is hidden, the presence of termites is often not discovered till the damage is beyond repair. Thus beams, flooring (Pl. XV, p. 28), walls and other woodwork, even up to the second and third floors, and furniture are reduced to mere outer shells, the interior being completely honeycombed; often these intervening longitudinal layers of wood that are left uneaten are reduced to the thinness and consistency of paper. Sometimes the settling of floors or the collapse of joists is the first indication that the building is infested. This often necessitates extensive repairing or complete rebuilding after tearing down and removing the infested timber.

However, the annual emergence of the winged adult termites is an indication of infestation and the point of emergence shows the approximate location of the infested timber. The presence of the earthlike tubes on timber or rock foundations of buildings is also a warning that the building is infested by termites.

While injury by termites in tropical regions affects not only the soundness of the building,¹ but the dry, hard wood of furniture and other contents as well, in this country attack is usually begun in moist or decaying foundation timbers. However, termites are able to extend their burrows throughout dry, hard wood and other dry substances, provided that there is access to moisture elsewhere; i. e., they make use of a mixture of moist frass and earth in creating more favorable conditions. Thus there is, in infested buildings, occasional damage to flooring, wooden partition walls, wainscoting, molding, door casing (Pl. IV, fig. 2), sills, window and door frames, wooden lath and wall plaster,² as well as to tiling or other interior construction made of wood pulp (Pl. V), furniture, wall paper, starched cotton curtains, and various stored material.

In infested buildings, where they have worked for several years, the insects having usually entered the house by means of joists or stringers in contact with the ground or set in concrete, work is begun in the flooring next to the walls, and burrows are excavated in toward the center of the room. The woodwork of coal bins in cellars sometimes becomes infested and is the cause of the insects gaining entrance to the flooring and other woodwork of the building.

Flooring, other woodwork, and furniture in infested buildings above boilers or furnaces where the temperature is high or the wood is moistened by hot steam are especially liable to attack.

In addition to the private residences, hotels, and business houses occupied by man, termites infest factories, granaries, barns, greenhouses, sheds, outhouses, and other wooden structures. The framework of wooden greenhouses, which are always warm and moist, is especially liable to attack and may be seriously damaged. The injury in these structures is extended to the wooden plant benches, plant tubs, label sticks, and sometimes to the growing plants.

Many other structures of wood are damaged by termites, any timber in contact with the ground being especially liable to attack.

¹ *Calotermes marginipennis* Latr., recorded from Central America (Mexico and Panama) and California, is especially injurious to the woodwork of buildings and other structures, and such injury in the Southwestern States and in California may be due to this or closely allied species of *Calotermes*. This species excavates chambers in the interior of the solid wood, rather than honeycombing it as do species of *Leucotermes*. (Pl. IV, fig. 1.) An indication of the infestation by *Calotermes* is the small oval sculptured pellets of excrement expelled by the insects. There is a record of damage to painted dry siding of a railroad business car at Los Angeles, Cal., by *Calotermes*, Apr. 6, 1915, and to the pine sill of a porch at Palm Beach, Fla., May 4, 1915, by *Cryptotermes cavirostris* Banks.

² In Baltimore, Md., and in Charlotte, N. C., the plaster laid on wood and patent metal lathing was probably only incidentally bored to allow the colonizing sexed adults to emerge at the time of the annual swarm.

Among these may be listed construction timber in bridges—there are only two actually recorded cases, one near Cambridge, Mass. (H. A. Hagen), and the other near Cleveland, Ohio (F. L. Odenbach)—wharves, and like structures; telephone and telegraph poles and poles used by electrical and other companies (in New York, New Jersey, Pennsylvania, West Virginia, southern Illinois, Indiana and Ohio, Missouri, Nebraska, California,¹ and in general the Southern States²); hop and bean poles; mine props and other timbers on the slope of incline mines (in West Virginia and Alabama); posts, lower rails, and boarding of fences; lumber piled on the ground; crossties (New Jersey, Virginia, Maryland, and the Southern States); improperly creosoted wood paving blocks (used as flooring in a factory building in Atlanta, Ga.; the wooden boxing or conduits of cables in the ground, to the detriment of the insulation; the woodwork in wells; wooden silo tanks; the ridge poles of tents, and tent pins (in desert near Boise, Idaho); wooden tree boxes; wooden beehives (near Shelbyville, Tenn.), the last being infested through wooden cross-pieces lying on the ground.

According to F. H. Chittenden much injury is done by white ants (*Lucifugus*) in hopyards. The dead roots, trellis poles made of red-wood, and pine string pegs are attacked in California.

There is evidence that termites not only injure man's habitations while alive, but also infest the last resting place of man on this earth, namely the pine boxes and coffins of the dead. Derry records extensive damage to skulls and bones generally by termites in graves in Egypt and Nubia,³ and these insects have been observed in several localities swarming in cemeteries. Furthermore, they often burrow deep into the earth, especially where they can follow down decaying wood, as in the woodwork of wells, etc. G. A. Dean, entomologist of the Kansas State Agricultural College, Manhattan, Kans., states that McCulloch observed a swarm of termites in a cemetery at Anthony, Kans., on January 19, 1914, in which the winged insects⁴ came out in enormous numbers and the ground was actually covered with them in several parts of the cemetery. The temperature at this time was about 70° F.

DAMAGE TO STORED MATERIAL.

Wooden electrotpe blocks (in New York, N. Y.) and other wood products, books in libraries or elsewhere, pamphlets, paper, documents (Pl. VI, fig. 1), and plans (Pl. VI, fig. 2), wood-pulp products,

¹ In California termite damage includes also that by *Termopsis angusticollis* Walker.

² In southern Georgia and the Gulf States termite damage to poles of bald cypress and southern white cedar (*Chamaecyparis thuyoides*) includes also that by *Caloterme* sp.

³ In many graves in Egypt and Nubia bones are found to be covered with a shell of earth; also in mummified bodies, where less bitumen or other preservative substances were employed, termites were able to make way through the cloth in which the body was wound, damage always being associated with earthwork and tunnels.

⁴ Probably *Leucotermes lucifugus*.



PRESSED WOOD-PULP TILE MINED BY TERMITES. BILOXI, MISS. (ORIGINAL.)

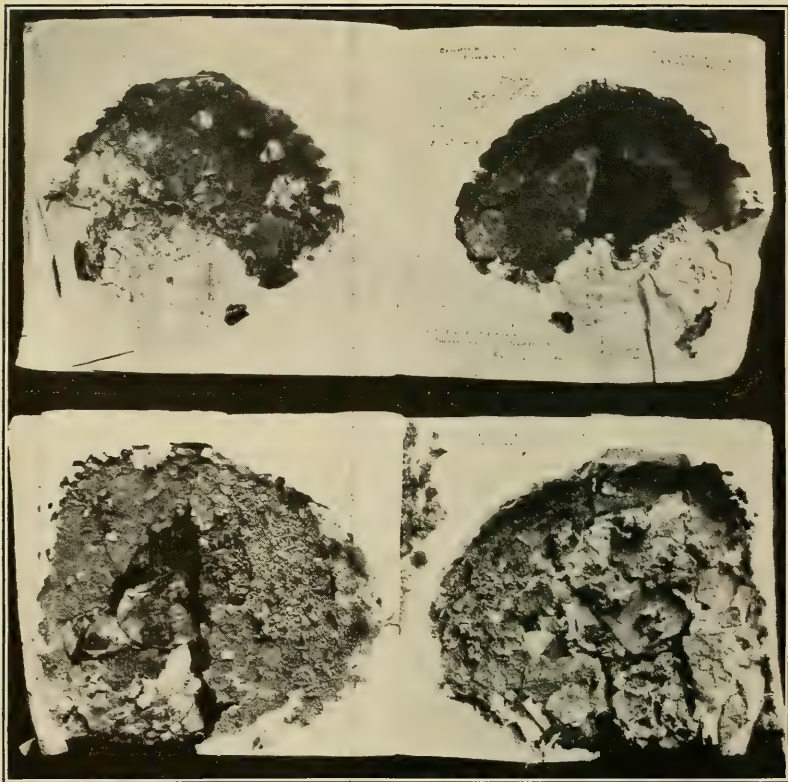


FIG. 1.—Termite work on railroad documents, Victoria, Tex., November 10, 1904. Photograph by W. E. Hinds. (Original.)

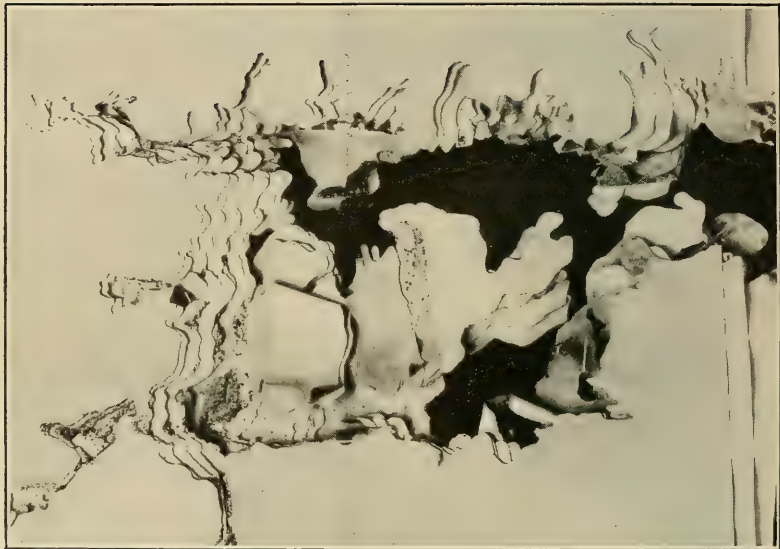
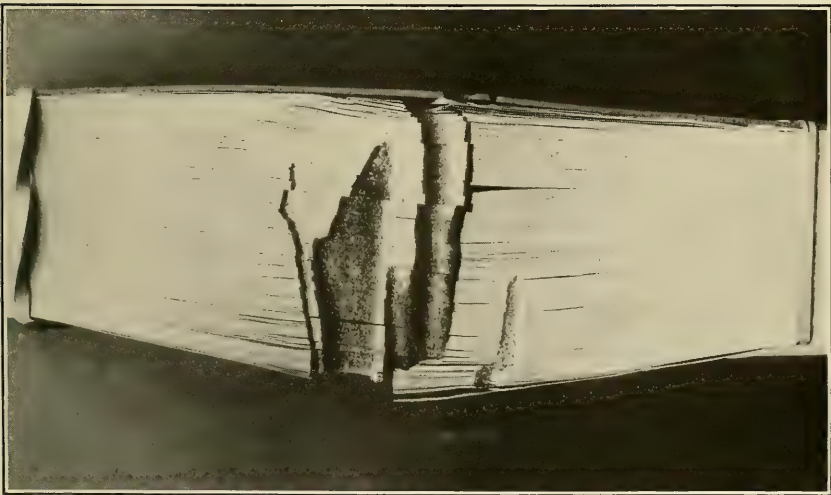
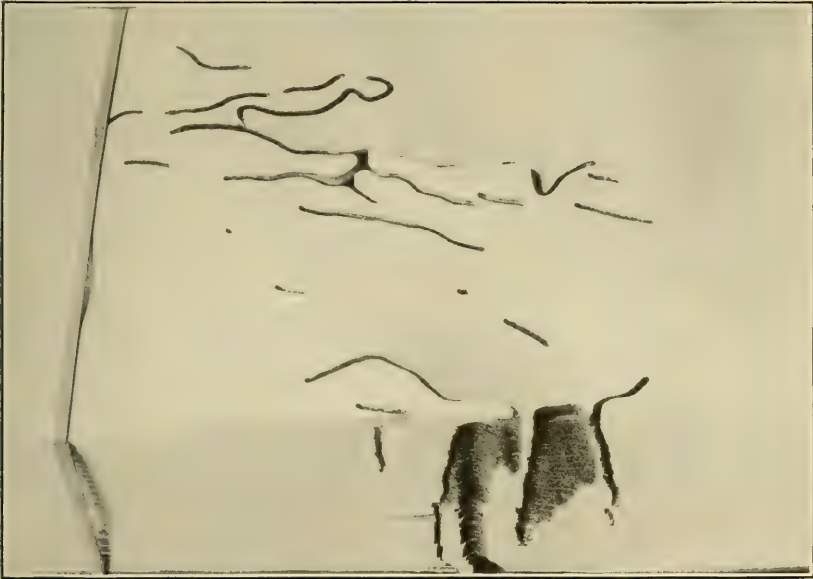
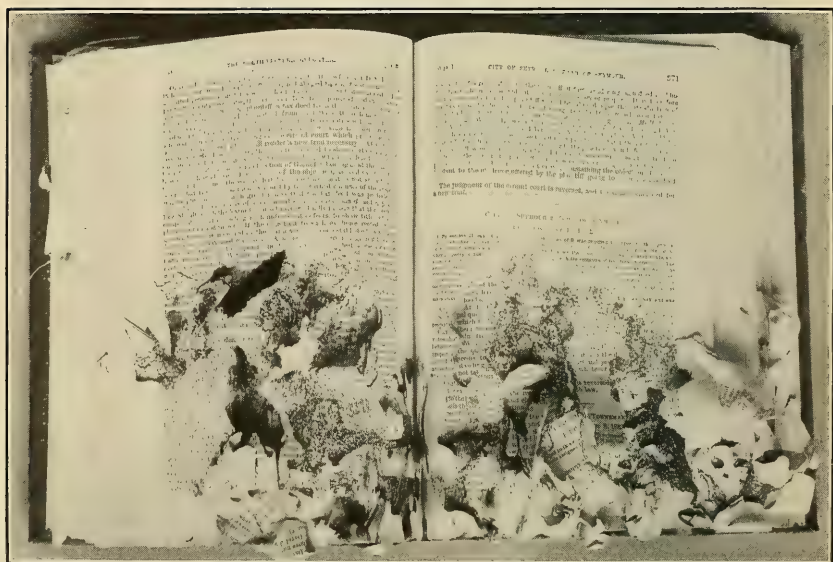
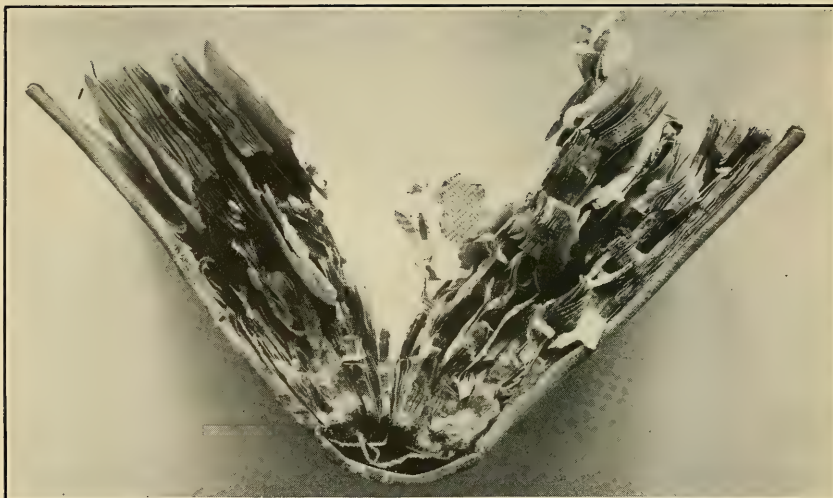


FIG. 2.—Plans at Washington (D. C.) Navy Yard damaged by *Leucotermes flavipes*. January, 1913. Photograph by C. H. Popenoe. (Original.)



Stored paper burrowed by termites (*Leucotermes flavipes*), the edges of the mines being covered with excrement. Atlanta, Ga. (Original.)

DAMAGE BY TERMITES TO STORED PAPER.



Book from library at Van Buren, Ark., ruined by termites. June, 1915. Views of book open and on end. (Original.)

VIEWS OF BOOK IN LIBRARY DAMAGED BY TERMITES.

pasteboard, rolls of cloth, and other fabrics, clothing, shoes, and other leather products, as well as food stored in dark, damp basements or similar moist places where the ventilation is poor, are sometimes seriously injured or destroyed by termites. At St. Louis, Mo., December 21, 1889, according to a correspondent of the Bureau of Entomology, termites bored through a full bolt of "Conestoga" ticking into wood about one-fourth to three-eighths inch in thickness. The ticking had been lying on a shelf for about a month and was covered with excrement where bored. Cotton yarn stored in a mill (Raleigh, N. C.) and cotton goods (Vincennes, Ind.) have been reported to be injured by termites. Entire stacks of books and paper (Pls. VII and VIII) are often completely penetrated and ruined by the burrows of these insects. W. S. Abbott has referred me to an instance at Manchester, N. H., where, according to E. J. Burnham,¹ documents were damaged in a cement vault in a basement, the insects probably entering in with the pine boards sheathing the vault. Similar cases have been recorded in Washington, D. C., and elsewhere. Termites usually infest this class of material indirectly through the moist or decayed wooden flooring, shelving, or casing on which the products are stored. At Cazenovia, Ill., paper lining under rugs and the carpets and rugs, where in their path, were eaten through, the insects coming up through the infested flooring underneath.

Some unusual cases of injury to other stored products have been furnished by F. H. Chittenden, in charge of Truck Crop and Stored Product Insect Investigations in the Bureau of Entomology; i. e., samples of flour received from New Orleans, La., in which were large lumps containing burrows made by *Leucotermes flavipes*, a few dead insects being still present in the same. The sacks containing this flour were unloaded on a platform under cover about the middle of November. The bottom sacks were cut as with a knife immediately above the floor and in these bottom sacks the lumps of flour were found that contained the white ants. Some sacks and bags received containing rice were injured in about the same way. The bottoms were eaten out of the sacks and the insects, by means of an adhesive substance, caused the rice to stick together at the bottom of the sacks. Another case of injury to stored rice occurred at Baton Rouge, La. Peanuts in store have also been attacked. On May 9, 1910, many layers of damaged bandage muslin (Pl. XIV, fig. 2), which had been lying on a wooden floor, were received from a Philadelphia hospital. The correspondent stated that this had happened a number of times.

¹ Burnham, E. J. Damage by white ants, *In Nature Study*, v. 3, no. 2, p. 201-203, Manchester, N. H., April, 1903.

DAMAGE TO FRUIT, NUT, SHADE, AND FOREST TREES.

Termites occasionally injure a great variety of living trees, bushes, and shrubs. In Florida, according to H. G. Hubbard, termites have caused considerable damage to newly planted groves of orange trees, the bark being eaten away about the collar and root and the tree completely girdled. There have been many records since then of injury to young orange trees in newly cleared land (Marlatt). Similar damage by termites¹ has been recorded to apple, pear, cherry, and plum trees in the Southern States and California,² the roots being attacked or the trees injured near the base. H. S. Smith states³ that "termites were reported to be damaging lemon trees in the vicinity of German-town" (California). On May 17, 1890, a piece of solid pear root damaged by termites was sent to the Bureau of Entomology from Mineral Park, Mohave County, Ariz. On May 9, 1902, a similarly damaged root of apple stock was submitted to the bureau from Moran, Okla.

Such damage is more common in the new soil of recently cleared woodland containing old decaying stumps or much humus. Similar damage by *Leucotermes* spp. is recorded to pecan, chestnut, and walnut.

Comstock records damage of the same kind to guava bushes in Florida, at or just below the ground.

In cities shade trees in great variety are injured by termites, the insects infesting the roots and the heartwood at the base of injured trees. Sometimes the infested trees are plastered with earthlike tubes or galleries.

In the forest termites rapidly⁴ render insect, fire, and disease killed timber unmerchantable. They also damage the roots and lower trunk of injured living trees, especially oak and chestnut, sometimes following the attack of large wood-boring beetle larvæ.⁵ In a letter dated October 24, 1915, A. B. Champlain states: "Termites are very bad on hickory saplings at Lyme, Conn. They quickly attack the infested trees, utilizing the *Magdalis* galleries, *Goes* galleries, or any other mode of entrance; in wounds on green trees as well as in trees of every stage of decay." Where the heartwood is decayed in living trees or in dead standing trees termites will work for considerable distances above ground (40 to 50 feet), completely honeycombing the interior. (Pl. IX, fig. 1.) The earthlike tubes, in the form of

¹ *Leucotermes* sp.

² Essig, E. O. Injurious and Beneficial Insects of California. Supplement Mo. Bul. State Com. Hort. California, v. 4, no. 4, 541 p. (p. 28-29), 503 figs., 1915. Damage by *Leucotermes lucifugus* to various species of fruit trees; i. e., apricot, cherry, lemon, orange, peach, and pear.

³ Smith, H. S. In Mo. Bul. State Hort. California, v. 4, no. 1, p. 53, Jan., 1915.

⁴ The rapidity of destruction varies with the resistance of the wood of the species of tree and the geographical locality.

⁵ Prionidae.

longitudinal tunnels or viaducts, constructed by termites often can be observed between crevices in the bark of infested dead and living trees to a considerable distance above the ground.

DAMAGE TO FIELD CROPS.

In the Southern States termites occasionally injure the stems and roots of a great variety of apparently healthy field crops, including both grain and truck crops, among which may be listed corn, cotton, sugar cane, rice, grasses, and a great variety of garden vegetables. In Kansas the species *lucifugus* is reported to inhabit dry vegetable and fibrous substances.

Injury of this character has been only occasionally recorded, and in consequence there has been, and is, considerable doubt as to whether termites are capable of attacking perfectly healthy living plants, it being usually considered that the plants attacked were previously either diseased or injured. However, termites are capable of such primary attack, although such injury in every case is not necessarily primary.

Comstock, as early as 1879, stated that in the Southern States termites infest living plants such as sugar cane (Florida) and pampas grass (Texas), attacking that part of the plant which is at or just below the surface of the ground. The bases or stalks of pampas grass are hollowed; in case of sugar cane the most serious injury is the destruction of the seed cane. On July 6, 1915, T. E. Holloway found workers and soldiers of *Leucotermes* sp. in burrows of *Diatraea* in sugar cane at New Orleans, La.

Kent states that at Roxie, Miss., termites¹ destroyed a good many cotton stalks during the summer of 1887, attacking the stalk just below the soil and eating out the interior, which would kill the plant in every instance.

F. H. Chittenden records injury to roots of cranberry at Borden-town, N. J.; also, in cases where the species of termite was not determined, to young squash plants at Brownsville, Mercedes, and Mission, Tex.

COTTON.

W. D. Hunter, in charge of Southern Field Crop Insect Investigations, has furnished the following field notes.

H. Pinkus, on June 22, 1910, in a cotton field on an irrigated farm at Lampasas, Tex., noticed many dead plants and some dying at certain places between healthy plants. Upon digging up the ground he discovered termites² destroying the stem about 2 inches below the surface of the soil, a hole being bored through the stem and into the heart of the plant; some plants were recently killed. Pinkus stated that on June 30, 1910, in a cotton field at Granbury,

¹ *Leucotermes flavipes*.

² *Leucotermes lucifugus*.

Tex., a number of dead plants were found that had been killed by termites. (Pl. X, fig. 1.) On July 2, 1910, in a field at Pearsall, Tex., a large cotton plant that had borne fruit was found already wilted, evidently very recently. When the soil was dug up about 3 inches deep from the surface and the plant moved, the stalk came off, clean cut, and the termites came out of its heart; the lower part of the plant was gone and only a few small roots could be found. E. S. Tucker states that on July 12, 1910, an examination of a cotton field at Plano, Tex., showed termites present and working in a few roots that had been killed by a root-rot disease; the stalks had been dead and dry for some time. The roots were badly bored. (Pl. X, fig. 2.)

POTATOES.

Injury by termites to potatoes has been recorded by C. L. Marlatt,¹ who states that a very common form of injury to those growing in rich soil or where there is a considerable quantity of decaying vegetable matter has often been noted. F. A. Marlatt discovered that white ants caused the damage, the injury to the tubers having the form of scars or pits covering the surface, the pits varying in shape from irregular holes to long, irregular excavations, sometimes extending far into the potato, but commonly to a depth of from one-eighth to one-fourth of an inch. In all cases these pits are more or less overhung and covered by the dead and dying skin, and are also lined with the cellular tissue of potato, showing that the insect cares most for the starch and water of the tuber. C. L. Marlatt now believes that the termite injury to the potato may possibly be secondary to that caused by the scab disease, since white ants frequently eat out scabby spots on potatoes. In the Tropics, however, otherwise sound potatoes are attacked by termites.

H. M. Russell found that sweet-potato tubers at Cutler, Fla., were being injured, the termites mining through the tuber and eating out nearly the entire interior. In most cases the insects entered the roots of the plants just below the earth and tunneled the stems. It is possible that termites similarly injure other tubers, as radishes, although there are no definite records. At Sabinal, Tex., on May 29, 1910, F. C. Pratt exposed a small colony of termites² in the ground while digging radishes.

CORN.

Injury by termites to corn has occasionally been recorded, as may be noted from the following field records of F. M. Webster, late in charge of Cereal and Forage Insect Investigations. G. G. Ainslie states that at Clemson College, S. C., on August 5, 1908, several dead stalks of corn were found in a cornfield; they proved to be hollowed out inside and

¹ Marlatt, C. L. The White Ant. U. S. Dept. Agr. Bur. Ent. Circ. 2d ser. no. 50. rev. ed., 8 p., 4 fig., January, 1908.

² *Eutermes* sp.; colonies commonly are found in the earth in the Southwest.

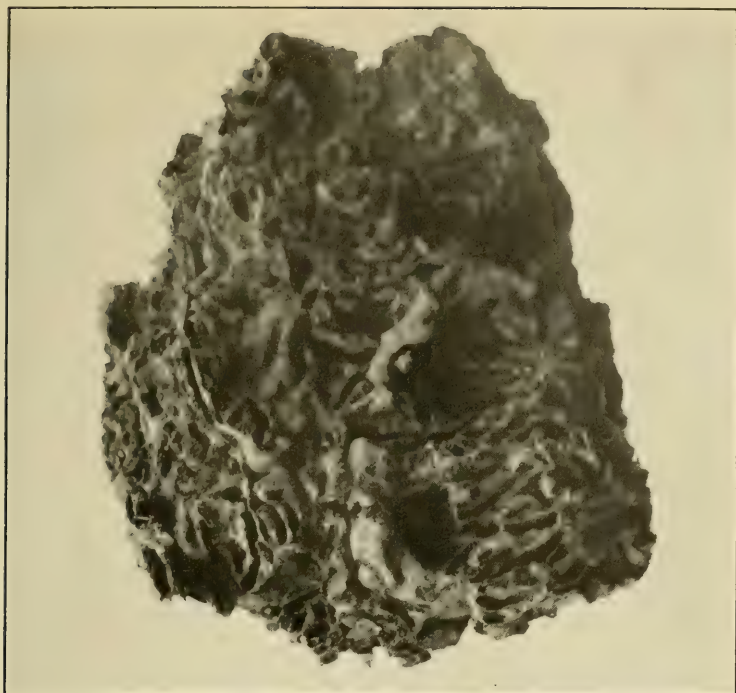


FIG. 1.—Heartwood of living chestnut tree disintegrated by *Leucotermes* sp. Falls Church, Va. (Original.)

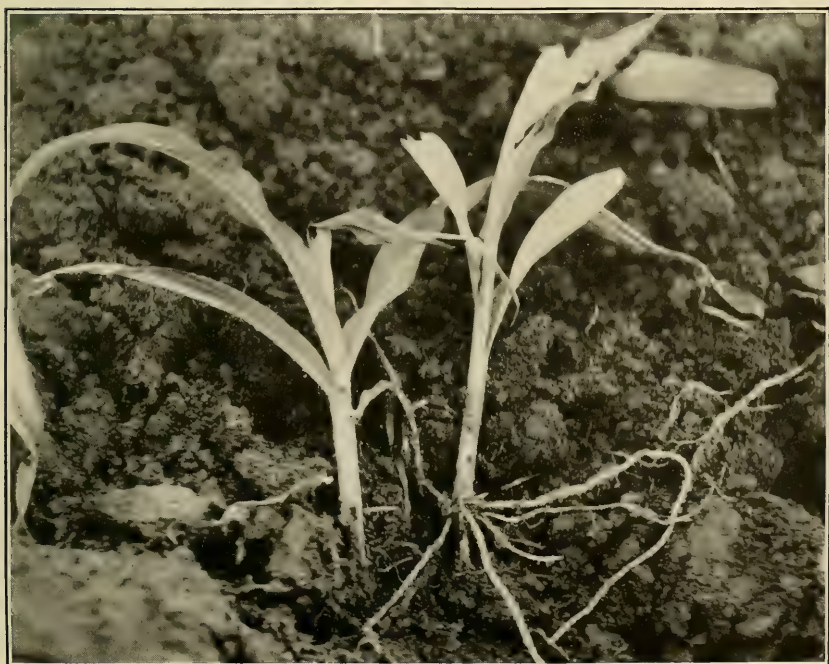


FIG. 2.—Small corn plants with the "bud" killed by termites. These insects cut a hole into the stem at the base, severing the central shoot, which is dead at the top. Hurricane Mills, Tenn., June 19, 1912. Photograph by G. G. Ainslie. (Original.)



FIG. 1.—Cotton roots injured by termites. Granbury, Tex., June 30, 1910. Photograph by H. Pinkus. (Original.)



FIG. 2.—Cotton roots affected by root-rot and attacked by termites. Plano, Tex., July 12, 1910. Photograph by E. S. Tucker. (Original.)

DAMAGE TO COTTON PLANTS BY TERMITES.

full of white ants.¹ In every case, however, the stalk showed that it had been attacked first by the larger corn stalk-borer (*Diatraea saccharalis* Fab.) and drilled about the base. It could not be determined whether the plant was dead when the white ants attacked it or whether they killed it. The stalk was drilled out and hollowed up to about 10 inches from the ground. The plants when killed were about 2 feet high. On October 30 Ainslie again found many stalks of corn full of white ants. The stalks which contain the termites can be ascertained as soon as touched. In most cases the entire inside has been eaten out, leaving a thin shell with a plug of untouched pith at the top. The stalk was usually entered at the bottom, underground. No forms but workers could be found. About 5 per cent of the stalks were infested, and each one contained from 5 to 75 workers.

Ainslie states that at Hurricane Mills, Tenn., June 19, 1912, in a field of young corn, numerous plants were found with these insects¹ mining in the ground and even up into the stalks. In most cases there was evidence to show that the termites had been attracted by some previous work of another insect and had merely kept on and enlarged the holes already started. These plants, by their dwarfed and deformed appearance, usually indicated the nature of the previous work. However, some plants were found which had been injured solely by these white ants. The plants were healthy and normal except for a wilting of the central leaf or two. The termites had cut smoothly elliptical holes into the stalk just below the surface of the ground, but these holes were too far above the roots to be those of any kind of "budworm." Within the holes the termites had excavated upward, taking the central core cleanly out, so that the amputated leaves would almost fall out in the wind. The colonies were not large, and it may be that the insects worked through passages from one central nest. This ground had been cleared many years and there were then no stumps or other rubbish in the field. (Pl. IX, fig. 2, shows the manner of injury.)

Similar injury to the stalk and taproot of corn has been recorded by several others in the field in North Carolina, Tennessee, and Alabama, the injury sometimes being primary, all castes being found in the stalks, and the insects apparently making permanent habitations in the plants. Termites breed in the stubble in the autumn, winter, and early spring, and later sometimes attack the young plants or the seed.

In Kansas E. O. G. Kelly made observations indicating similar injury to corn in the field. At Wellington, Kans., on August 8, 1910, he states that several colonies of termites² were burrowing in corn-stalks. Some of the stalks had been bored for three to four joints,

¹ *Leucotermes flavipes*.

² *Leucotermes* sp. (probably *lucifugus*).

and the joints were simply shells. The tops of the plants attacked were dying. The termites seemed to prefer the pith. Some of the colonies were quite large and had attacked two or three stalks in one hill. On the 12th of August termites were active in five different cornfields. They had not attacked many plants in any area, but had severely bored those that were attacked, great hollows having been made by them. Some of the injured stalks had been previously attacked by *Sphenophorus maidis* Chittn., or other insects, but not all of them. The insects seemed to enter at a scar or break about the roots; none were above the ground. On the 22d of August Kelly found that quite a number of corn plants had been attacked by these insects and that the stalks were mere shells, having had the pith removed. No serious injury appeared to have been done to the plants, because most of them were small. By September 6 the corn plants were getting quite dry and the termites seemed to be increasing. In a cornfield on one farm there were numbers of attacked plants. This field was an old prairie field and had been planted to corn the year before. There were no decaying stumps or wood of any kind in the field, and the termites evidently subsisted on the cultivated crop. On October 14, 1910, the termites were still active, burrowing in the dry cornstalks. A colony dug out contained thousands. The ground was filled with their burrows. Their nest did not seem to be anything but a series of burrows with young larvæ, etc., here and there all through them. On November 26 the termites were still burrowing in the stalks. On February 15, 1911, with the temperature at 75° F. and the ground quite warm at noon, there was a swarm in a cornfield, along roadsides, and even from sidewalks in the city limits. On May 9 many termites were found in a cornfield that was planted to corn the year before; nine young plants had been injured. Single dead stalks sometimes contained 32 termites.

Similar damage to a living corn plant about 1 foot high, tunneled by white ants and not previously injured, was found by J. J. Davis on June 18, 1915, at West La Fayette, Ind.

H. E. Smith states that on May 8, 1913, in a field of corn $1\frac{1}{2}$ miles northwest of Mulvane, Kans., he found that this species¹ had eaten all the seed before germination in about 6 feet in the row, and they were apparently working straight down the row. No others could be found in the field.

DAMAGE TO NURSERY STOCK, YOUNG PLANTATION STOCK, AND VINEYARDS.

There are numerous records of termite injury to young fruit and nut-tree seedlings in nurseries, to other nursery stock, and to young trees planted in recently cleared ground or soil rich in humus. The

¹ *Leucotermes* sp. (probably *lucifugus*).

injury, however, has been only occasional and not extensive, and usually has not been considered serious. The stock is usually attacked at a scar, where the roots have been injured or cut off, or at a graft, as "cleft-graft" apple stock.

APPLE.

At Wellington, Kans., on November 14, 1910, E. O. G. Kelly states that on several occasions dying and dead apple sprouts in a nursery had been severely burrowed. An examination of 3-year-old stock showed that the roots and body of a number of the trees had been burrowed in the same manner as the sprouts, and the termites¹ were in the burrows in these larger trees. About 5 per cent of the stand would have to be discarded on account of their ravages. The pest had been injurious for a number of years and was worse in dry years than in wet. The 3-year-old trees were quite badly damaged when they were put out in 1909, because the early spring was so dry. The 2-year-old trees were not very badly infested during the fall of 1910. Quite a number of young sprouts were girdled, and the result of girdling is a dead tree. A count in three rows of the 2-year-old stock gave results of 8, 7, and 12 per cent, or an average of 9 sprouts out of every 100, infested. In the spring or 1-year-old stock the infestation was quite severe. The rows near the hedge fence were 15 to 30 per cent infested; out farther, from 6 to 70 per cent were infested. The severe infestation ran in local spots, not being general over the field, but there were infested plants in all parts of the field (Pl. XI). An adjoining cornfield was badly infested, numbers of stalks being bored by them. Some of the trees were full of the insects, while some had been abandoned. On November 26 the termites were still active and burrowing in the apple sprouts. Peach sprouts and shade-tree sprouts in the same nursery were injured.

PECAN.

Herrick states that in Mississippi, in a pecan nursery where there was damage by termites, injury was most prevalent to seedling pecans of the 1-year growth.

A. L. Quaintance, in charge of Deciduous Fruit Insect Investigations, states that numerous reports relative to injury to pecan nursery trees by white ants have come from various parts of the pecan-growing area, as Texas, Florida, Mississippi (Pl. XII), Louisiana, etc. W. B. Wood investigated a case of serious infestation of a pecan nursery in the neighborhood of Petersburg, Va. An inspection, on October 8, 1912, of this nursery, which consisted largely of pecan trees varying in age from 1 to 4 years, showed that the severest injury to the

¹ *Leucotermes* sp. (probably *lucifugus*).

trees occurred on stock 1 and 2 years old. Trees that had reached an age of 3 years showed little injury. This difference was probably due to the fact that the trees 1 and 2 years old were planted on recently cleared woodland, whereas the old trees were on old land, though closely adjacent to the badly infested area. Of the trees 1 and 2 years old probably one-fourth of the total number had been destroyed during the summer, the injury being almost entirely below ground, although the excavations made by the termites occasionally extended an inch or two above the surface of the soil inside of the tree. Below ground the trees were frequently hollowed out until little more than a shell of bark remained. The insects made their entrance to the trees at some point below ground, the place most frequently chosen being the point where the taproot had been cut to cause it to branch out into a larger root system. From this point of entrance the insects worked upward, extending their galleries through the wood and enlarging them until the heart of the tree at the crown was entirely eaten away. Usually the affected trees did not show any indication of injury until they were badly damaged and then they died very quickly, the leaves sometimes drying on the limbs within a period of three or four days.

VINEYARDS.

Injury by termites to vineyards has occasionally been recorded in Algeria,¹ in Bordeaux, France, and in North America. Usually only the weak or old vines with many pruning scars are attacked, or dead or injured parts, or ramifications of the stem or branches invaded by other pests, the healthy ramifications of the stock being exempt from invasion. Signs of attack are sickly foliage or abortive buds, or the injury is observed at the time of cutting down to stock or making graftings. S. H. Scudder records fatal injury to the roots of grapevines in forcing houses at Salem, Mass.

DAMAGE TO SHRUBS, FLOWERS, AND GREENHOUSE STOCK.

GREENHOUSE STOCK.

Termites injure a variety of shrubs, flowers in gardens as well as in greenhouses, and weeds. Hagen states that our common native termite,² introduced into Europe, so nearly destroyed one of the largest of the beautiful hothouses at Schoenbrunn belonging to the Emperor of Austria that it had to be torn down. Besides the beams, the termites destroyed the tubs in which the plants were set. Hagen states in 1876 that a few years before he had observed termites swarming in clouds in the Botanical Garden at Cambridge, Mass. Manured

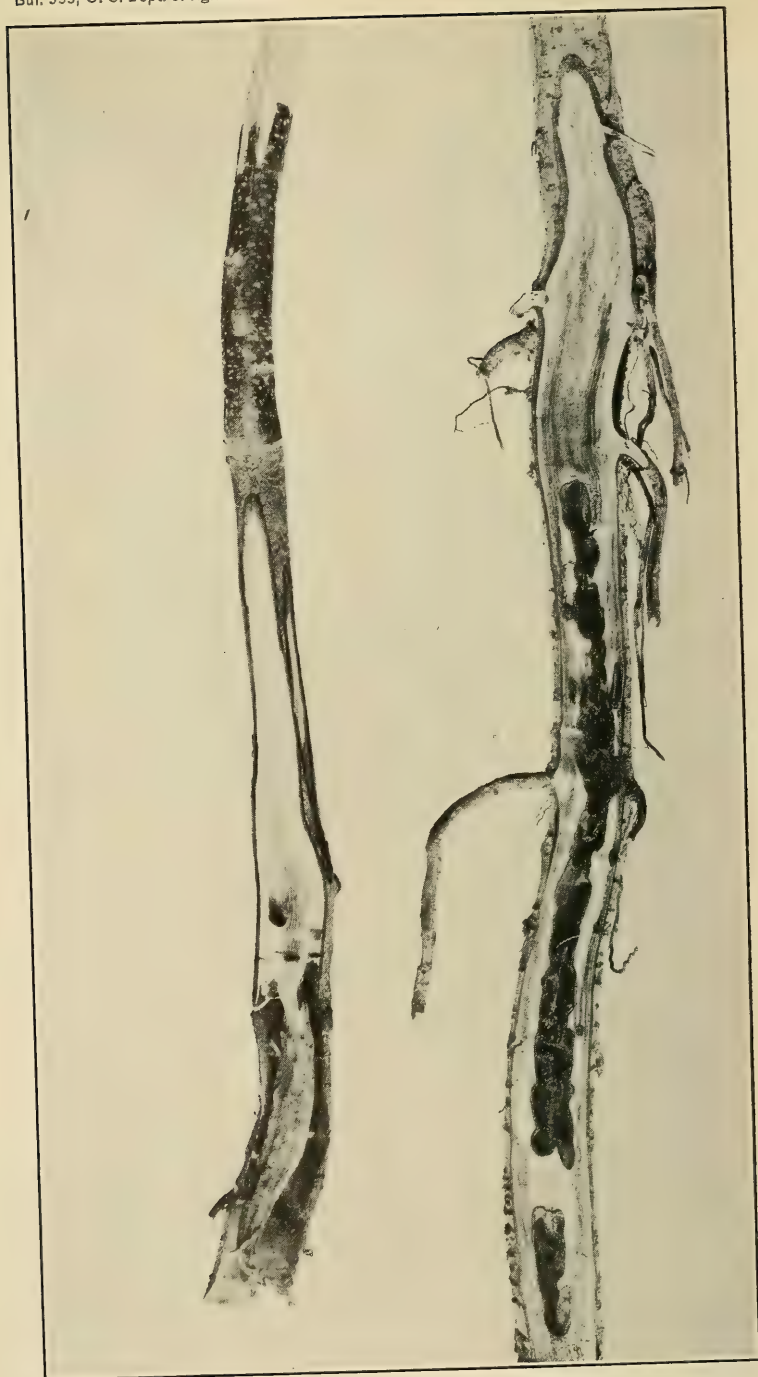
¹ By *Calotermes flavicollis* Fab.

² *Leucotermes flavipes*.



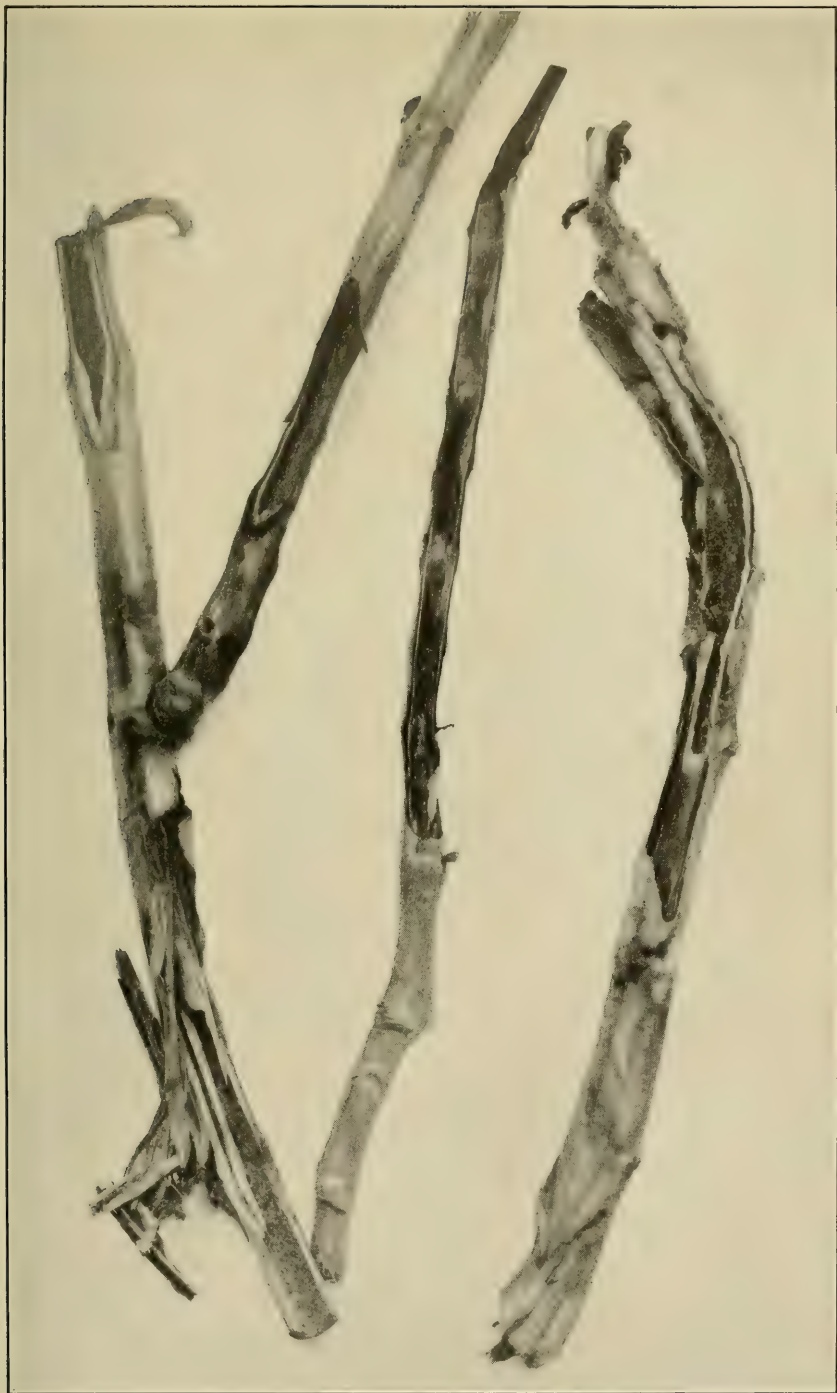
TERMITE DAMAGE TO NURSERY STOCK.

Damage to apple seedlings by *Leucotermes* sp. at Wellington, Kans. November, 1910. Photograph by E. O. G. Kelly. (Original.)



TERMITE DAMAGE TO NURSERY STOCK.

Pecan nursery stock killed by *Leucotermes flavipes*. Wortham, Miss., July 14, 1913.
Photograph by J. H. Paine. (Original.)



TERMITE DAMAGE TO GARDEN PLANTS.

Geranium stems burrowed by "white ants." Damage extensive in lath house and garden at Brownsville, Tex., 1915. Photograph by C. H. Popenoe. (Original.)



flower beds around the walls of wooden buildings are a source of infestation by termites. The soil in such beds is always less compact and warmer, and termites have been observed by Hagen swarming from such beds.

Webster states¹ that in 1896 termites were destructive in Ohio, burrowing in the roots of small trees. He figures the injuries to geranium cuttings that were being propagated in a greenhouse near Cincinnati, the termites destroying many cuttings by eating them off the benches.

Chittenden states that the common white ant (*flavipes*) was recorded some years ago as occurring quite commonly on plants grown under glass, and that it is directly injurious to such growing vegetation as greenhouse geranium (Pl. XIII), chrysanthemum cuttings, and other herbaceous plants, especially those with large stems or more or less woody stalks. The stalks found to be injured had been tunneled through and through by the white ants, and at the bottom near the roots the plants had given way to the inroads of numerous individuals. Several plants were killed outright. The causes of such attack can easily be traced to the colonies in old sticks that are used for recording the date of setting out, etc., and the termites mining in wooden benches. One such case was reported by L. C. Corbett, of the Bureau of Plant Industry, who stated that large begonia plants at Morgantown, W. Va., had been injured in a similar manner. Infestation was due to the undermining of the bench structure beneath the plants, the insects having burrowed through the wood up through the drainage holes in the bottoms of the pots. Florists are sometimes sorely tried by these insects and state that "they attack everything." Roses grown in greenhouses are sometimes badly injured by the girdling of the white ants. While partial to geraniums and chrysanthemums, termites, as shown by the records of the Bureau of Entomology, injure jasmine, pansies, and oleander. Wooden benches and plant pots are infested, as well as the woodwork of the buildings, the insects coming up through the ground from outside colonies. Termites may be considered a serious greenhouse pest. According to G. A. Dean, entomologist of the Kansas State Agricultural College, on January 29, 1915, termites² swarmed in a greenhouse; there was a swarm in the same greenhouse on December 26, 1914. W. E. Britton states³ that more than 200 geranium plants had been ruined by termites,⁴ which tunneled out the inside of the stem and main roots in the field at New Rochelle, N. Y.

¹ Webster, F. M. Some Particularly Destructive Insects of Ohio. Ohio Agr. Expt. Sta. Bul. 68, p. 19-58, 6 pls., 1896.

² *Leucotermes lucifugus*.

³ Britton, W. E. Injury to Geraniums by White Ants. In 14th Rpt. Connecticut State Ent. f. 1914 (Conn. Agr. Expt. Sta. Rpt. f. 1914, pt. 3), p. 196-197, 1915.

⁴ *Leucotermes* sp.

ORNAMENTAL PLANTS.

F. C. Pratt states that at Sabinal, Tex., on July 11, 1910, some small pieces of *Opuntia* infested with *Mimorista* larvæ were entirely covered with soil galleries by termites. Many insects were found. It was also noticed that the galleries were extended to the healthy plants. Most of the small pieces were shriveled, but this condition was primarily due to the termite attack. This injury to ornamental cacti has occurred many times before.

On August 24, 1915, at Jacumba, Cal., F. P. Keen found workers and soldiers of *Hamitermes* sp. feeding on the surface of the rind of *Yucca*, where protected by the leaf bases, which are closely appressed to the stalk. The insects worked between the rosette of leaves and the flower stem. Jacumba is near the International Boundary Line and in a desert region.

At Washington, D. C., termites (*L. flavipes*) constructed earthlike tunnels around a wooden fern box in a window of a school building in October, 1915. When the insects came to a hole in one corner of the box—bored to allow the excess water to drip away—they suspended hanging tubes down through this hole. These were about 3 inches in length and $1\frac{1}{2}$ inches in width at the bottom—the widest point. The opening at the bottom, through which the antennæ of the workers and soldiers could be seen projecting, was about $\frac{1}{4}$ inch in diameter. The shape of these tubes was somewhat like a funnel but the flare was not quite so marked. Termites infest the roots and stems of ornamental plants, in gardens or potted.

WEEDS.

E. S. Tucker states that on July 30, 1909, at Dallas, Tex., termites¹ occupied the hollow roots of a weed, *Leptilon canadense*. The insects had effected entrance through a hole in the root. On September 29, 1911, at Wellington, Kans., according to E. O. G. Kelly, termites had attacked stems of cocklebur, utilizing the entrance hole made by *Papaipema nitela* Hbn. At Colorado Springs, Colo., on March 7, 1915, at an elevation of 6,100 feet, live termites¹ were noted by G. Hofer in the dead stem of the common thistle.

PREVENTIVE AND REMEDIAL MEASURES.

PREVENTIVES.

PROTECTION OF WOODWORK IN BUILDINGS.

The fact that the beams, as "joists," "studding," "stringers," etc., of the basement are embedded in concrete is only a partial protection. In the settling of the house concrete is almost sure

¹ *Leucotermes* sp.

to crack, allowing avenues of ingress, and the beams and joists put down in the moist material soon partially decay and become exceptionally good breeding places. From such beams the white ants carry their burrows up through the timbers of the first and even second floors (Marlatt). Flooring commonly becomes infested through the wooden beams or stringers laid directly on the earth or in moist concrete; untreated beams should never be laid on the earth and the spaces filled in with concrete, or in moist concrete, since they will rot, even if they do not become infested. An air space should intervene. Therefore the foundations of buildings should be entirely of brick, stone, or concrete, including the basement floor, without beams or joists sunken in the ground or concrete, and especially should this method of construction be followed in tropical and subtropical regions. H. von Schrenk, of St. Louis, Mo., states that in no case should timber joists be completely surrounded with mortar or brick; there should be an air space completely around the joists so as to permit air circulation.

Marlatt states that complete dryness is an important means of rendering buildings safe from attack. Books and valuable documents, etc., should not be packed away in unventilated chambers where they may become moist and moldy, as they are then particularly subject to attack by white ants, which are very likely to be present in old buildings, even though their work has not been sufficient to bring them into special notice.

USE OF RESISTANT WOODS.

Certain species of woods are highly resistant to termite attack, due to the presence of oils, alkaloids, gums, or resins as well as to hardness and other factors.

Maj. George Ahern, United States Army, reports, according to Marlatt, that California redwood has been used for more than 25 years in the Philippines and has never been known to be injured by white ants. Its use in Manila is very general, especially in the construction of cabinets, filing cases, etc., where it is desirable to protect valuable papers from these insects. Redwood is not resistant against termite attack in contact with the ground in California.

Another resistant North American cabinet wood is black walnut; of the tropical species, teak, mahogany, and "peroba" are resistant woods.

As to timber to be set in contact with the ground, E. Gerry gives data¹ on the durability of native hardwoods; of the conifers, incense cedar, eastern red cedar or juniper, western red cedar, and southern bald cypress are resistant. Durable and resistant exotic structural

¹ Gerry, Eloise. Tyloses: Their occurrence and practical significance in some American woods. *In Jour. Agr. Res.*, v. 1, no. 6, p. 445-470 (p. 463-464), pl. 52-59, Mar. 25, 1914.

timbers are teak, greenheart, *lignum-vitæ*, etc. "Karri" (*Eucalyptus diversicolor*) and "jarrah" (*E. marginata*), of Australia, are resistant although not immune to attack by termites.

REMEDIES.

LOCATION OF DAMAGE TO WOODWORK IN BUILDINGS.

The point of emergence of the flying termites may indicate approximately the location of the infested timbers; if the insects are not observed swarming, large numbers of the dead winged adults or the discarded wings will be found near by. Frass and earth thrown out of crevices through which the insects emerge are also evidence. In efforts to stop further damage by termites in buildings it should be realized that the numbers of these insects may be constantly recruited from some undiscovered, outside central colony. The destruction of the winged, colonizing adults at the time of the emergence, while advisable in preventing the establishment of potential new colonies, is of no value in eradicating the insects infesting the woodwork.

Another indication of infestation is the presence of longitudinal earthlike tubes, of small diameter, constructed on foundation timbers or other woodwork, or over the surface of stone, brick, or other impenetrable foundation material from the ground to the woodwork. Drenching the ground—where these tubes originate—with kerosene oil will afford relief. A prompt examination of the foundation timbers, such as beams and joists in contact with the ground, should be made to determine the approximate point of entrance of the insects and the extent of the damage already accomplished. It may be necessary to tear up the flooring and other woodwork to accomplish this. The foundation timbers and interior woodwork found damaged should be removed and burned and the ground where they were set drenched with kerosene oil.

ROCK FOUNDATIONS AND WOOD PRESERVATIVES.

The main point is to prevent the insects from gaining access to the woodwork from colonies in the ground, either by means of substituting rock or concrete foundations and concrete or tile flooring in the basement or by protecting the foundation timbers in contact with the ground by impregnation of the wood with coal-tar creosote.

It is very rarely possible to find and destroy the external colony, and it may be necessary to replace the foundation of the buildings with walls and floorings of stone, concrete, or other form of rock composition, and this is the most permanent and complete preventive. In the case of the National Museum buildings, the Carnegie Institution of Washington, and several private edifices in Washington,

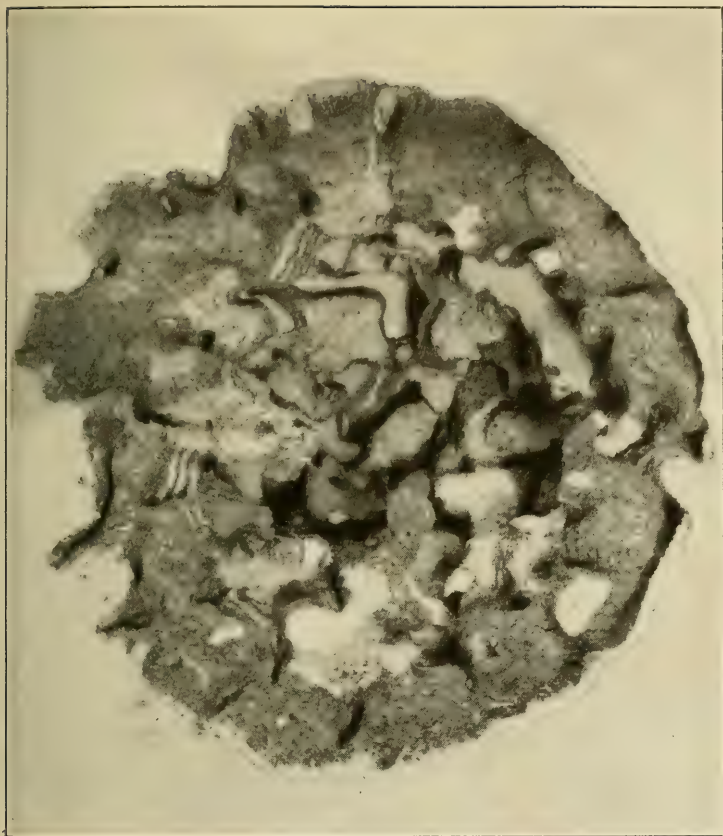


FIG. 2.—Layers of bandage muslin lying on wooden floor of a hospital in Philadelphia, Pa., destroyed by termites. Photograph by C. H. Popenoe. (Original.)

DAMAGE BY TERMITES.

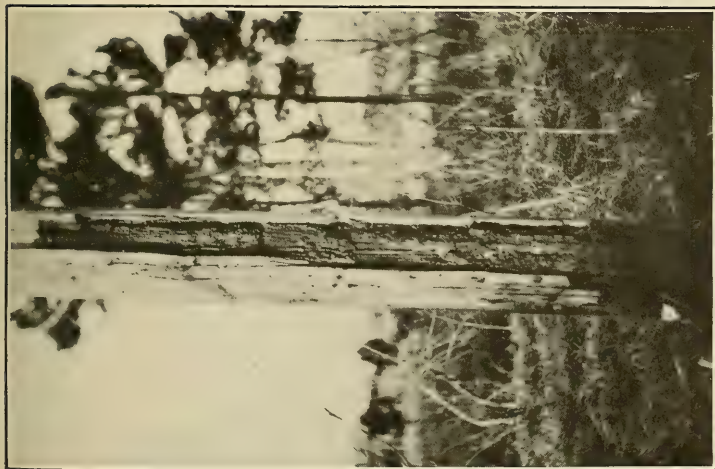


FIG. 1.—Injury by "white ants" to yellow-pine pole impregnated with 12 pounds of coal-tar creosote per cubic foot in a telephone line set along Gulf coast near Pass Christian, Miss., since 1899. Average penetration of the preservative, 1½ inches; surface intact; insects entered through deep season checks; damage more extensive above ground line. Shell of outer layers of wood broken away to show eaten-out interior. Photograph by American Telephone and Telegraph Co. (Original.)

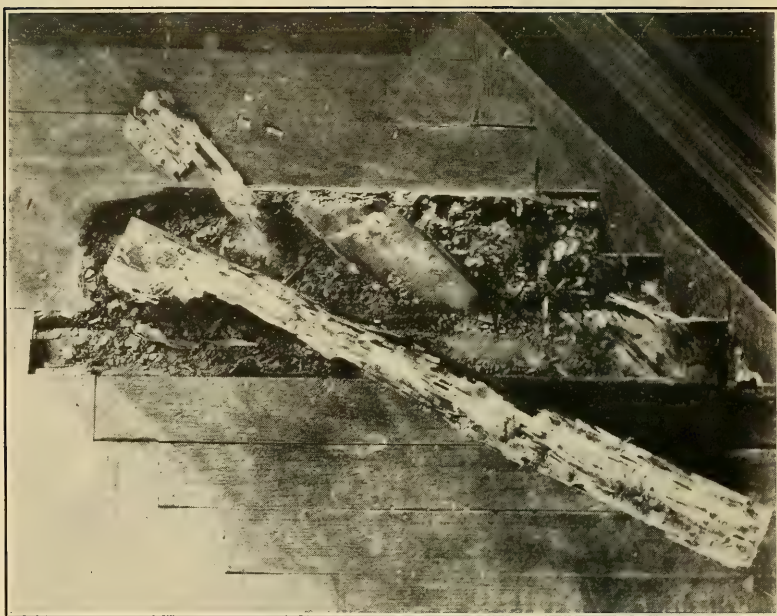


FIG. 1.—Oak floor honeycombed by *Leucotermes flavipes*. Washington, D. C., July, 1915.
Photograph by C. H. Popenoe. (Original.)



FIG. 2.—Pine subfloor underneath the oak floor shown in figure 1.
Photograph by C. H. Popenoe. (Original.)

D. C., this course was finally adopted, with the result that white ants were completely excluded and their work terminated (Marlatt). This measure was also necessary in the case of the buildings of the State Agricultural College at Manhattan, Kans., where wooden partitions, floors, and other woodwork were torn out and cement floors and walls substituted.

If the foundation of the building is such that damage to the woodwork is extensive and likely to recur, and it is impracticable to replace with concrete or stone, it is advisable to replace the exposed interior woodwork with wood impregnated by a 6 per cent solution of zinc chlorid or a 1 per cent solution of bichlorid of mercury; except in case of flooring in contact with the ground or in wet situations, where such preservatives would leach out.

In case of greenhouses iron frames and concrete work should, wherever possible, replace woodwork, and woodwork should be impregnated with bichlorid of mercury. Wood impregnated with this preservative can be painted after treatment.

In some cases thorough and repeated drenching of infested timbers, where accessible, with kerosene oil may afford temporary relief and kill some of the white ants. Kerosene oil should be poured into the crevices through which the winged insects emerge from infested wood. As the insects may have entered the house through soil channels by means of pillars or the supports of porchings and steps, these last should be removed if damaged and the ground soaked with kerosene.

OTHER TIMBER IN CONTACT WITH THE GROUND.

Poles,¹ mine props,² railroad ties, posts, construction timber, and other wood in contact with the ground should, since these insects attack all classes of wood to which they can attain access from the ground, be treated with chemical preservatives to render them more resistant to termite attack. Superficial methods, temporarily prolonging the length of service of timber, include brush and dipping methods of treatment. From experiments it has been determined that for timber in contact with the ground brush and dipping treatments with coal-tar creosote will render southern yellow pine resistant for at least two to three years in the Southern States and effective for from three to four years and longer. Under the closed-cylinder pressure process ("full cell" treatment) of impregnation of southern yellow-pine timber with coal-tar creosote, at least 16 years' service is attained in

¹ Snyder, T. E. *Insects Injurious to Forests and Forest Products*. U. S. Dept. Agr. Bur. Ent. Bul. 94, pts. 1-2, 85 p., 16 pl., 14 fig., 1910-1915. *Damage to Telephone and Telegraph Poles by Wood-boring Insects*. U. S. Dept. Agr. Bur. Ent. Circ. 134, 6 p., 3 fig., Mar. 7, 1911.

² Snyder, T. E. *Insect Damage to Mine Props and Methods of Preventing the Injury*. U. S. Dept. Agr. Bur. Ent. Circ. 156, 4 p., July 13, 1912.

the Southern States¹ (Pl. XIV, fig. 1). After many years' service there may be a deterioration in the treated wood. Other chemical preservatives are in use, but coal-tar creosote is usually the most effective preventive since it is also a fungicide and will not leach out in wet situations. For permanent timbers to be used in coal mines a pressure process with zinc chlorid has been found more suitable, according to tests conducted by the Forest Service.

CABINET WOODS.

Impregnation of cabinet woods, furniture, etc., with chlorinated naphthalene² is effective in rendering wood more resistant to termite attack; treated, perishable, northern cabinet hardwoods comparing favorably with untreated teak and mahogany after two and one-half years' test.

WOOD-PULP PRODUCTS.

Treatments have been tested for wood-pulp products, such as the various wood-fiber, "processed," or "composition" boards used for interior finish and as substitutes for lath, etc., when they are to be used in the Tropics and portions of the southern United States to prevent attack by white ants. It has been found that the practical method is to add various poisons during the manufacture of these boards.

Experiments with such poisons and insecticides as white arsenic, bichlorid of mercury, zinc chlorid, copper sulphate, sodium fluorid, phenol, and dihydrogen potassium arsenate (KH_2AsO_4) have been conducted by manufacturers upon the recommendation of the Bureau of Entomology. It has been determined that where insoluble chemicals were added in the process of manufacture of the board there was so low a retention that the cost rendered the treatment commercially impossible. Also in the manufacture of the board a large amount of water is employed which it is not practicable to save, and consequently a large amount of chemical, whether soluble or insoluble, is carried away. As yet the results of these tests do not warrant the drawing of definite conclusions.

Dihydrogen potassium arsenate is a powerful insecticide,³ is soluble in cold water, and should prove as effective as the insoluble white arsenic. Sodium fluorid has been proved, by experiments of A. L. Quaintance, an effective insecticide and is also being tested as

¹ In the Tropics and along the Gulf coast of the United States, where seasonal checking of timber is liable to occur after treatment and setting, a penetration sufficient to prevent white ants from infesting the timber through these checks should be secured. A more uniform penetration with a practical minimum to allow for checking, and a heavier impregnation (at least 15 pounds per cubic foot) are necessary. The depth of penetration can be determined roughly by the thickness of the sapwood.

² Process devised by the Western Electric Co., of New York.

³ Information on this insecticide was obtained from the Branch of Southern Field Crop Insect Investigations from the experiments of B. R. Coad.

a treatment to render timber more resistant to attack by insects. Wood soaked in a 2 per cent solution is under test.

STORED MATERIAL.

Injury to books, paper, documents, and other stored material or products is usually indirect, the insects as a rule burrowing through such material only where it is in contact with infested wood. Hence, since the source of infestation is decaying wood, if the insects can be kept out of wooden structures this damage can be prevented. When once the source (white ants coming up through the earth where there is moisture) is shut off, the insects infesting stored material soon die out or can be killed by spreading out infested books, documents, and other stored material or products to dry in the sun or in an oven. Later they can be restored to the repaired building or a safer place. Most damage of this sort can be prevented by the substitution of concrete foundations to buildings or by using timber impregnated with coal-tar creosote.

FUMIGATION.

Where the injury is confined to books and papers, other stored material, or exposed woodwork and furniture, hydrocyanic-acid gas fumigation can be attempted, exposing if possible also, by opening up floors, the infested joists beneath and spreading out the books and opening cases and wardrobes. As hydrocyanic-acid gas is poisonous and dangerous, fumigation should be attempted only by those with experience.¹

LIVING TREES.

Owing to the subterranean habit of termites, it is extremely difficult to prevent or remedy injury to living forest, fruit, or shade trees. Care should be taken that the trees do not become scarred near the base, in order to prevent heart rot and subsequent infestation. Proper clean forest, orchard, and horticultural management is to be recommended. Properly executed tree surgery² sometimes may be effective in repairing damage to valuable old trees. Dead and dying infested trees should be removed and burned. Prunings should not be left lying on the ground, but should be burned.

NURSERY STOCK, FIELD CROPS, AND VINEYARDS.

Injury to nursery stock will be most serious on recently cleared land where there is abundant decaying wood. Such débris, in which the insects breed, should be removed. In general, the use of recently

¹ For a description of the use of hydrocyanic-acid gas see Howard, L. O., and Popenoe, C. H., *Hydrocyanic-acid Gas Against Household Insects*, U. S. Dept. Agr., Farmers' Bul. 699.

² Collins, J. F. *Practical Tree Surgery*. In U. S. Dept. Agr. Yearbook for 1913, p. 163-190, pl. 16-22, 1913.

cleared land should be avoided in planting nursery stock. In case of nursery stock, Herrick recommends the growing of two or three cereal crops on newly cleared land before setting out pecan stock, and suggests experiments with commercial fertilizers. Experiments with commercial fertilizers and chemical compounds to determine whether they will serve as preventives are to be conducted by the Bureau of Entomology.

Sometimes injury by termites to corn in Kansas, according to Marlatt, is due to the method of plowing under old stubble, in which the insects breed. This practice should be discontinued if there is serious damage by white ants. Allowing the land to lie fallow for one year before planting should be of value; the same can be said of deep fall plowing. The practice of better farming methods, with rotation of crops, will prevent damage to field crops.

In case of vineyards care should be taken in pruning operations to reduce the surfaces cicatrized; all dead or diseased vines should be removed. Cuts should be painted over with coal tar. The various mastics employed in grafting may prove to be effective preventives. Prunings should not be left lying on the ground, but should be burned.

FLOWERS AND GREENHOUSE STOCK.

In case of flower or truck gardens, especially where near the woodwork of buildings, less animal manure should be used, in order to protect not only the building but also the plants.

In greenhouses the removal of decayed infested wood will prevent the plants from becoming infested in turn. Iron frames and concrete work should wherever possible replace woodwork, and woodwork should be impregnated with bichlorid of mercury. Wood impregnated with this preservative can be painted after treatment.

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UNITED STATES DEPARTMENT OF AGRICULTURE



BULLETIN No. 334



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WM. A. TAYLOR, Chief

Washington, D. C.

PROFESSIONAL PAPER

December 28, 1915

DIRECTIONS FOR BLUEBERRY CULTURE, 1916.¹

By FREDERICK V. COVILLE, *Botanist*.

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SPECIAL REQUIREMENTS.

Success in blueberry culture rests especially on the recognition of two peculiarities in the nutrition of these plants: (1) Their requirement of an acid soil; (2) their possession of a root fungus that appears to have the beneficial function of supplying them with nitrogen.²

If blueberries are planted in a soil with an alkaline or neutral reaction, such as the ordinary rich garden or fertile field, it is useless to expect their successful growth. In such a situation they become feeble and finally die. Blueberries require an acid soil, and they thrive best in that particular type of acid soil which consists of a mixture of sand and peat. (See Pl. I.)

Good aeration of the soil is another essential. It is commonly but erroneously supposed that the swamp blueberry (*Vaccinium corymbosum*), the species chiefly desirable for cultivation, grows best in a permanently wet soil. It is to be observed, however, that the wild plants of the swamps occupy situations which, though perhaps submerged in winter and spring, are exposed to the air during the root-

¹ Revised by the author from the original paper of 1913, entitled "Directions for Blueberry Culture," which was published, without illustrations, as pages 3 to 11 of Circular 122, Bureau of Plant Industry, and was also separately printed.

² For a full discussion of the principles of blueberry culture, including the soil requirements and peculiarities of nutrition of the blueberry plant and the details of the growing of seedlings, consult "Experiments in Blueberry Culture," Bulletin 193, Bureau of Plant Industry, 1910, or the corrected reprint of 1911. Although the edition of this bulletin was long since exhausted at the Department of Agriculture, copies may be obtained from the Superintendent of Documents, Government Printing Office, for 25 cents each.

forming period of summer and autumn or, when growing in permanently submerged places, they build up a hummock or a cushion of moss which rises above the summer water level and within which the feeding roots of the bush are closely interlaced. In actual culture, moreover, it has been found that the swamp blueberry does not thrive in a permanently wet or soggy soil.

Although some species of *Vaccinium*, such as the common low-bush blueberry of the northeastern United States, *V. angustifolium* (called *V. pennsylvanicum* by some authors), grow and fruit abundantly in sandy uplands that are subject to drought, the swamp blueberry grows best in soils naturally or artificially supplied with adequate moisture.

These, then, are the three fundamental requirements of successful blueberry culture: (1) An acid soil, especially one composed of peat and sand; (2) good drainage and thorough aeration of the surface soil; and (3) permanent but moderate soil moisture. Under such conditions the beneficial root fungus which is believed to be essential to the nutrition of the plant need give the cultivator no concern, for even if the necessary fungus were wholly lacking in the soil of the new plantation each healthy bush set out in it would bring its own supply of soil-inoculation material.

Next in importance to soil conditions is a convenient location with reference to a good market. The berries should reach their destination without delay, preferably early in the morning following the day of picking. To secure the best prices they should also reach the market about the beginning of the main wild-blueberry season. A situation to the south of the great areas of wild blueberries in northern New England, Canada, and northern Michigan is therefore desirable. One of the most promising districts for blueberry culture is the cranberry region of New Jersey, for there an ideal soil occurs in conjunction with an early maturing season and excellent shipping facilities to the markets of Philadelphia, New York, and Boston.

Situations liable to late spring freezes, such as the bottoms of valleys, should be avoided, for while the blueberry plant itself is seldom injured by freezing, its crop of fruit is often destroyed in this way.

In seasons in which the wild crop of upland blueberries has been destroyed by late spring freezes, it has been observed that in or around bodies of water, such as cranberry reservoirs or cranberry bogs temporarily flooded to prevent frost or insect injury, the wild bushes often produce normal crops of blueberries. It may be found that provisions for flooding blueberry plantations will save a crop often enough to warrant the installation of flooding equipment. In locating a blueberry plantation, therefore, it would be well to choose a situation that could be flooded, if flooding proved later to be commercially advantageous.

IMPORTANCE OF SUPERIOR VARIETIES.

In the southern United States and in the Middle West blueberries are not ordinarily distinguished from huckleberries, but in New England the distinction is very clearly drawn. The name huckleberry is there restricted to plants of the genus *Gaylussacia*, the berries of which contain 10 large seeds with bony coverings like minute peach pits, which crackle between the teeth. The name blueberry is applied in New England to the various species of the genus *Vaccinium*, in which the seeds, though numerous, are so small that they are not noticeable when the berries are eaten. It is probable that the comparatively low estimation in which this fruit is held in the South is largely due to the lack of a distinctive popular name and the consequent confusion of the delicious small-seeded southern *Vacciniums* with the coarse large-seeded *Gaylussacias*. It is the culture of the small-seeded blueberries only, as distinguished from the large-seeded huckleberries, that is here advocated.

From the market standpoint, the features of superiority in a blueberry are sweetness and excellence of flavor; large size; light-blue color, due to the presence of a dense bloom over the dark-purple or almost black skin; "dryness," or freedom from superficial moisture, especially the fermenting juice of broken berries; and plumpness, that is, freedom from the withered or wrinkled appearance that the berries begin to acquire several days after picking. Large berries cost less to pick than small ones and bring a higher price. A berry eleven-sixteenths of an inch in diameter has already been produced under field culture, and others of still larger size are to be expected.

Although blueberry plantations may be formed by the transplanting of unselected wild bushes or by the growing of chance seedlings, neither of these courses is advocated, because neither would result in the production of fruit of an especially superior quality. Seedling plants, even from the largest berried wild parents, produce small berries as often as large ones. Until nurserymen are prepared to furnish plants asexually propagated from superior stocks, the cultivator should begin by the transplanting of the best wild bushes, selected when in fruit for the size, color, flavor, and earliness of the berry and the vigor and productiveness of the bush. These he should propagate by layering and by cuttings until his plantation is completed. Through a combination of these methods, a valuable old plant can be multiplied by several hundred at one propagation, the fruit of the progeny retaining all the characteristics of the parent.

PROPAGATION.

While grafting and especially budding are useful in experimental work, neither method is suitable for commercial plantations, because blueberry bushes are continually sending up new and undesirable shoots from the stock. The best season for budding for experimental

purposes is from the middle of July to the end of August. The ordinary method of shield budding, with dry and unwaxed raffia wrapping, has proved the most successful of all the methods tried. The best wood on which to bud is the lower portion of vigorous basal shoots of the season, especially those from plants that were cut to the stump in the preceding winter. On such shoots the bark can be lifted with ease much later in the season than on older stems. Special care must be taken that the raffia wrapping does not become wet and fermentation ensue between the raw surfaces of bud and stock, in the first three weeks. By that time, in normal cases, the bud wood has united with the stock, and if the budded stem has increased in diameter sufficiently to cause pronounced choking by the raffia the wrapping should be removed. If choking does not occur the wrapping may be allowed to remain until spring, when the stem is cut off above the still dormant bud. In greenhouse experiments, a growth of over 8 feet has been secured from an inserted bud in its first growing season, all other growth from the stock having been promptly rubbed off as soon as it started.

STUMPING.

The easiest way to propagate the swamp blueberry is by a special process of layering named "stumping." The directions are as follows:

1. In late fall, winter, or spring, preferably in early spring before the buds have begun to push, cut off at the surface of the ground either the whole of the plant or as many of the stems as it is desired to devote to this method of propagation. The stems that are cut off are discarded, or they may be used for cuttings, as described under "Tubering" or "Winter cuttings."

2. Cover the stumps to the depth of 2 to 3 inches with a mixture of clean sand and sifted peat, 2 to 4 parts of sand to 1 of peat, by bulk. A rough box or frame may be built on the ground to keep the sand bed in place.

3. Care must be taken that the sand bed be not allowed to become dry except at the surface during the summer.

4. The new growth from the stumps, which without the sand would consist of stems merely, is transformed in working its way through the sand bed into scaly, erect, or nearly erect rootstocks which, on reaching the surface of the sand, continue their development into leafy shoots. (See Pl. II.) Although roots are formed only sparingly on the covered bases of stems, they develop abundantly during spring and early summer on these artificially produced rootstocks, and by the end of autumn all the shoots should be well rooted at the base. They should remain in place in the sand bed till late winter or early spring, undisturbed and exposed to outdoor freezing temperatures; but the sand should be mulched with leaves, preferably those of red oaks.

5. Early in the following spring, before the buds have begun to push, open the bed and sever each rooted shoot carefully from the stump. Discard the upper portion of the shoot, making the cut at such a point as to leave on the basal portion about three buds above the former level of the sand bed. If the cut at the basal end of the rooted shoot is not smooth or the wood is cracked, recut the surface with a sharp thin-bladed knife. The discarded upper portion of the shoot may be used for winter cuttings, as described on pages 8 to 11.

6. Set the rooted shoots in a coldframe or a cool greenhouse in clean earthenware pots of suitable size, ordinarily 3-inch pots, in a soil mixture consisting of two parts, by bulk, of rotted upland peat and one part of sand.

7. Cover the frame with muslin or other white shade suspended above the glass, giving the plants plenty of light but no direct sunlight, and for the first two or three months keep the temperature at not to exceed 65° F. if practicable. When subjected to high temperatures the newly cut shoots are liable to die and rot from the base upward. The outer surface of the pots should never be allowed to become dry. The desired condition may be assured by bedding, or "plunging," the pots in moist sand up to the rim.

8. Watering should be as infrequent as practicable, only sufficient to keep the soil moist but well aerated.

9. The frame should receive ventilation, but not enough to cause the new twigs to droop. These are most susceptible to overventilation and to overheating when they have nearly completed their growth. (See Pl. III.)

10. After the new twigs have stopped growing and their wood becomes hard new root growth takes place. Then secondary twig growth follows, either from the apex of the new twigs or from another bud lower down on the old wood of the original rooted shoot. Until this secondary twig growth takes place the life of the plant is not assured.

11. Those plants that make sufficient growth to require repotting during the first summer should be set in clean pots of 2 inches larger diameter in a standard blueberry-soil mixture.

SOIL MIXTURE FOR BLUEBERRIES.

A very successful potting mixture or nursery-bed mixture for blueberry plants consists of one part of clean or washed sand, nine parts of rotted upland peat, either chopped or rubbed through a sieve, and three parts of clean, broken crocks, that is, pieces of ordinary unglazed, porous, earthenware flower pots. No loam, and especially no lime, should be used. Manure is not necessary, and in the present state of our knowledge may be regarded as dangerous, although in small quantities it serves to stimulate the plants, at least temporarily. The danger from manure apparently lies in its tendency to injure the beneficial root fungus of the blueberry plant.

The use of broken crocks in the potting mixture is based on the fact that the rootlets seek them and form around them the same kind of mats that they form at the wall of the pot, thus increasing the effective root surface and the vigor of growth. If crocks are not available, the soil mixture should consist of 2 to 4 parts of peat to 1 part of sand.

The peat most successfully used for potting blueberry plants is an upland peat procured in kalmia, or laurel, thickets. In a sandy soil in which the leaves of these bushes and of the oak trees with which they usually grow have accumulated and rotted for many years, untouched by fire, a mass of rich leaf peat is formed, interlaced by the superficial rootlets of the oak and laurel into tough mats or turfs, commonly 2 to 4 inches in thickness. These turfs, ripped from the ground and rotted from two to six months in a moist but well-aerated stack, make an ideal blueberry peat. A good substitute is found in similar turfs formed in sandy oak woods having an underbrush of ericaceous plants other than laurel. The turfs of low-bush blue-

berries serve the same purpose admirably. Oak leaves raked, stacked, and rotted for about 18 months without lime or manure are also good. The leaves of some trees, such as maples, rot so rapidly that within a year they may have passed from the acid condition necessary for the formation of good peat to the alkaline stage of decomposition, which is fatal to blueberry plants. Even oak leaves rotted for several years become alkaline if they are protected from the addition of new leaves bearing fresh charges of acidity.¹ The much decomposed peat in the submerged lower layers of deep bogs, such as is used for fuel in Europe, is not suitable for blueberry-soil mixtures.

TUBERING.

By ordinary methods, cuttings of the swamp blueberry have been rooted only in occasional instances. Successful special methods, however, have now been devised for these plants. Wild stocks of the swamp blueberry vary greatly in their response to propagation by a particular method, and it is likely to prove true that one variety of cultivated blueberry can best be propagated by one of the methods here described, others by another. The most novel of the methods devised, but the one easiest of operation, is that of tubering. This method involves the same principle as that employed in stumping, namely, the forcing of new shoots in such a manner that their basal portions are morphologically scaly rootstocks, with a strong rooting tendency. The directions for tubering as applied to the swamp blueberry are as follows:

1. Make stem cuttings from outdoor plants between midwinter and early spring, before the buds have begun to make their spring growth, and preferably on a warm day when the twigs are not frozen. A still better plan is to make the cuttings in autumn after the leaves have fallen, and store them for about two months in moist sphagnum moss on ice at a temperature just above freezing.

2. The cuttings are to be made from vigorous plants grown in well-lighted situations and with stems therefore well stored with starch. Use unbranched portions of the old and hardened branches and stems, about a quarter of an inch to an inch, or even more, in diameter. From 3 to 4 inches is a suitable and convenient length. Make the cuts with pruning shears or a fine-toothed saw and remove the bruised wood at the cut ends with a sharp knife. Be careful not to injure the bark or split or strain the wood.

3. Lay the cuttings horizontally in a shallow box or other cutting bed of pure clean sand and cover them to the depth of about half an inch. Moisten the sand well with rain water, bog water, or other pure water (free from lime) from a sprinkling pot, and see that the sand is closely and firmly packed about the cuttings. Cover the box or cutting bed with a pane or panes of glass, the top of the box being flat, so that the glass fits it rather snugly. The box should be so prepared that any surplus water in the sand will drain away beneath through holes in the bottom covered with clean broken crocks and sphagnum moss.

¹ For a fuller discussion of the conditions under which leaves decompose into leaf peat as distinguished from leaf mold, and the fundamentally different effect of the two on the growth of plants, consult "The Formation of Leafmold," Smithsonian Report for 1913, pp. 333 to 343 (also separately printed).

4. Keep the box at a temperature of 55° to 65° F., or as near those limits as practicable. A temperature of 70° or over is likely to ruin the cuttings.

5. In order to avoid excessive temperatures, do not allow direct sunlight upon the glass, either keeping the box by north light or keeping it shaded, as by a white cloth or paper cover suspended several inches above the glass, or in a shaded greenhouse.

6. Keep the air inside the box saturated with moisture. This condition will be evidenced by the condensation of the moisture on the under side of the glass during the cooler part of the day or whenever a cold wind blows against the glass.

7. Watering should be as infrequent as practicable, only sufficient to keep the sand moist but well aerated and the atmosphere in the box saturated. If the glass fits tightly, a second watering may not be needed for several weeks.

8. Within a few weeks new growth will begin to appear above the sand. (See Pl. IV, fig. 1.) When the shoots have reached a length proportionate to their vigor, commonly 1 to 3 inches, their further growth is self-terminated by the death of the tip. After the leaves have reached their full size and acquired the dark-green color of maturity the time has come for the development of roots.

9. When the first shoot has reached this rooting stage a half-inch layer of finely sifted rotted peat, 2 parts, and clean sand, 1 part, should be placed on the surface of the cutting bed and moistened well with water. A time-saving and perhaps desirable modification of this treatment is to use this mixture of peat and sand as the original covering of the cuttings, described in paragraph 3.

10. The new growth, which if it had originated above the sand would be like an ordinary shoot, was transformed in working its way through the sand and became a scaly, erect rootstock, which on reaching the surface of the sand continued its development into a leafy shoot. During the spring and early summer, roots form in abundance on the lower or rootstock portion of these shoots. (See Pl. IV, fig. 2.)

11. After a shoot is well rooted it commonly, though not invariably, makes secondary twig growth the same season, usually from a bud in the axil of the uppermost leaf. If the rooting of the shoot has not already been ascertained by direct examination, the making of such secondary growth is good evidence that rooting has actually taken place.

12. When a shoot is well rooted, with roots 1 to 2 inches in length, it is ready to be potted. (See Pl. V.) If the shoot has not already disconnected itself from the dead cutting, it should be carefully severed with a sharp knife. In the process of tuberizing, the behavior of the cuttings is essentially identical with that of real tubers, like those of the potato. The original cutting dies, but the sprouts that arose from it root at the base and form independent plants.

13. The rooted shoots should be potted in clean 2-inch earthenware pots in the standard blueberry-soil mixture already described. (See Pl. VI.)

14. The pots should be bedded in moist sand up to the rim in a glass-covered frame or box, well lighted but protected from direct sunlight, and slightly ventilated but with a saturated or nearly saturated atmosphere.

15. In order to secure rapid growth, the rooted plants should be gradually accustomed to a well-ventilated atmosphere and then to half sunlight, this adjustment extending over a period of about three to four weeks.

16. If preferred, the rooted shoots may remain in the original cutting bed until the following spring, the cutting bed being exposed during the winter to freezing temperatures, but mulched with oak leaves, and the plants may then be transferred, with their whole root mat intact, to a peat and sand nursery bed at a spacing of about a foot each way.

Where propagating is to be done on a sufficiently large scale, outdoor coldframes may be used instead of cutting boxes. Miss Elizabeth C. White, of New Lisbon, N. J., who has brought together the best existing collection of selected wild-blueberry stocks, has been propagating them with much success in muslin-shaded coldframes by the method of tubering, and she has much simplified the handling of the cuttings, both before and after rooting. The cuttings are made in the late fall, packed in boxes in loose, moist, clean sphagnum moss, and stored during the winter in a cool cranberry house at a temperature of about 40° F. As soon as the frost is out of the ground beds of clean sand are laid down in the coldframes and the cuttings are pressed into the sand until the upper side is level with the surface. The whole is then covered with an inch layer of sifted peat (about 2 parts) and sand (1 part). The frames are completely shaded by muslin on a framework about 7 feet above the ground (Pl. VII), and ventilation is not begun until most of the shoots are rooted, about midsummer. The shades and sash are removed in early October, and in late autumn, after most of their leaves have fallen, the rooted plants are taken out of the frames, so that these can be made ready for a new lot of cuttings very early the next spring. The stronger of the rooted plants taken out of the frames are set at once in their permanent places in the field plantation. Those less strongly rooted are placed in nursery beds at a spacing of about 10 inches each way, where they remain during the winter and the following growing season.

WINTER CUTTINGS.

The rooting of leafy cuttings of the blueberry in summer is very difficult, because in a temperature above 70° F. the cuttings blacken and die. With the aid of a shaded greenhouse, winter cuttings can be started early enough to make roots before warm weather comes on. Similar results can be secured in coldframes so located, sheltered, and manipulated as to prolong their low temperature as late as possible into the season.

The essentials of a successful coldframe for blueberry propagation are: (1) That it be located on the cool, shaded, north side of a building or in some other situation where it will not receive reflected heat from neighboring structures. (2) The frame must receive an abundance of light but no direct sunlight, a condition best secured in the case of isolated frames by the use of clean white muslin shades. Frames on the north side of a building will also require shade in early morning and late afternoon from March to September. On sunless days all shades should be removed, so that the cuttings will receive as much light as possible. (3) There should be ample space for the circulation of cool air between the frames and the shade. A shade at the height of about 7 feet from the

ground not only allows such circulation but makes it easy to work among the frames. (4) The frames should be kept closed until the cuttings are rooted. This closing not only keeps the air saturated with moisture and prevents the drying of the cuttings, but it also tends to maintain a cool ground temperature within the frame.

When frames are thus located, constructed, and managed, the maximum temperature on sunny days within the frames is often 10 degrees lower than the shade temperature outside, and the period of safety for cuttings that are not yet rooted is greatly prolonged. Low temperatures can be maintained in such coldframes much later in the season than in a greenhouse of the ordinary construction, even though the greenhouse is well shaded and well ventilated.

The use of a greenhouse in which to start the cuttings, followed by the transfer of the cutting boxes to coldframes at the beginning of warm weather, permits an even more prolonged protection of the cuttings than can be secured in either greenhouse or coldframe alone and increases the percentage of rooted plants.

The directions for rooting winter cuttings of the blueberry by the use of a coldframe are as follows:

1. Make the cuttings in late winter before the buds have begun to swell. If more convenient, they may be made in late autumn, after the leaves have fallen, laid rather loosely in clean moist sphagnum in a covered but ventilated box or other package, and stored until early spring on ice at a temperature just above freezing or in commercial cold storage at a temperature of about 35° F., if such storage is available.

2. Make the cuttings from wood of the preceding summer's growth, rejecting such portions as bear the large fat flowering buds. The cuttings are to be made from well-matured unbranched twigs or shoots grown in well-lighted situations, and therefore well stored with starch. Excellent wood for cuttings is afforded by the long stout shoots that grow the first summer from a blueberry plant that has been pruned to the stump. In the swamp blueberry these have few or no flowering buds and often are 3 to 5 feet in height and a quarter of an inch or more in diameter at the base.

3. About 4 to 5 inches is a suitable length for finished cuttings. A sharp thin-bladed knife should be used. In the finished cutting the upper end of the diagonal cut at the base of the cutting should come just below a sound bud, and the cut at the upper end of the cutting should be about an eighth of an inch above a sound bud. If the cuts are first made with pruning shears, remove with the knife the bruised wood at the cut ends. The diagonal knife cuts should be as short as is practicable without bruising the bark or splitting or straining the wood. Cuttings that have been kept in cold storage should be recut at both ends, so as to present clean surfaces that show no discoloration. In order to avoid infection of the cuttings, the knife must be kept clean. This may be done conveniently by dipping the blade in alcohol and wiping it on a clean towel. The cuttings must not be allowed to become dry. This is easily prevented by laying them in the fold of a clean moist towel.

4. The coldframe may be of the usual form, the top about 1 foot above the surface of the cutting bed at the front and 2 feet at the back, and tightly constructed of material not less than an inch in thickness, with closely fitting sash of the ordinary kind. The cutting bed, 4 inches in depth, should be laid down over a groundwork of gravel or other material that will provide good

drainage. On this groundwork place about 1 inch of clean chopped sphagnum moss and over the moss about 3 inches of pure clean sand. Moisten the sand with clean rain water or other pure water (free from lime) from a sprinkling pot.

5. After making deep slits at suitable intervals in the sand with some clean implement, set the cuttings in the slits at a spacing of about 2 to 3 inches each way according to size, the base of the cutting being in the sand a little above the sphagnum, and see that the sand is so closely and firmly packed about the base of the cutting that the cut surface is in contact with the sand, but be careful not to injure the delicate raw tissue at the base of the cutting by pushing forcibly into the sand. Smooth the surface of the bed by a final watering. Cover the frame closely with the sash, so that the air within will be moist.

6. Do not allow the temperature inside the frame to go above 65° F. Prolonged temperatures above 70° are likely to ruin the cuttings. Do not, on the other hand, allow the cutting bed or the cuttings to freeze.

7. Shade the frame with white muslin at a height of 2 to 7 feet above the frame, so as to keep the sunlight off the glass and at the same time to permit a sweep of air between the glass and the shade. The shade should be so arranged as to be removable on cloudy days or at any time when the frame is shaded by other objects.

8. Keep the air inside the box saturated or nearly saturated with moisture. This condition will be shown by the condensation of the moisture on the under side of the glass at night or at other cool portions of the day.

9. Watering should be as infrequent as practicable, only sufficient to keep the sand moist but well aerated and the atmosphere in the box saturated. If the sash fits tightly, the period between necessary waterings may extend over several weeks.

10. After the cuttings have callused at the base, the new twigs have pushed from the upper buds (Pl. VIII) and their growth has been terminated by the browning of the tips, and the new leaves have reached their full size and acquired the dark-green color of maturity, when the formation of roots is about to begin, the surface of the bed is to be mulched with about half an inch of a mixture of sifted peat, 2 parts, and clean sand, 1 part, carefully watered after application, so that some of the acid water from the peat will be carried down into the sand bed about the base of the cuttings. (See Pl. IX, fig. 1.)

11. When all or most of the cuttings in the frame have begun to root, ventilation of the frame should be begun. The best superficial evidence that a cutting has rooted is the development of secondary twig growth, either from the apex of one of the first set of new twigs or from another bud lower down on the old wood of the cutting. (See Pl. IX, fig. 2, and Pl. X.) If secondary growth does not take place, the development of a plump but dormant bud at the apex of one of the leafy twigs is also good evidence that the cutting has begun to root. Cuttings that are healthy but not yet rooted at the time ventilation begins usually die from excessive transpiration.

12. Ventilation should be only slight at first and should be increased very gradually, the transition to full ventilation extending over a period of several weeks. If any of the sensitive secondary growth begins to wilt, reduce the ventilation immediately until the wilting ceases. Be especially careful not to give too much ventilation on windy days.

13. All cuttings that are dying should be removed from the bed at once. Those injured by too high temperature usually turn brown at the base first, the dead area progressing upward until the new growth collapses. Those otherwise sound but suffering from excessive ventilation before they are rooted usually indicate their bad condition by the marginal yellowing of their leaves before they drop and the stems become withered.

14. The plants are best left in the open coldframe all winter, mulched with leaves, preferably oak leaves, and in the early spring, before the buds have begun to push, they should be very carefully lifted and moved, with the whole root mat and adhering soil intact, to a peat and sand nursery bed at a spacing of about a foot each way.

ROOT CUTTINGS.

The early experiments with root cuttings gave such a small percentage of rooted plants that further experiments in the greenhouse were abandoned. At Whitesbog, N. J., however, in order that the roots as well as the tops of selected wild plants might be utilized, cuttings of the roots were made about 3 to 4 inches long and of all sizes down to a little less than an eighth of an inch in diameter. These were given the same treatment as tubered cuttings in coldframes. A high percentage of rooted plants resulted. (See Pl. XI.) This may prove to be one of the most satisfactory methods of propagating plants that have large root systems.

TREATMENT OF YOUNG PLANTS.

When blueberry plants, either large or small, are grown in porous pots, the surface of the pot should never be allowed to become dry, for the rootlets which grow through the soil to the wall of the pot for air are extremely fine and easily killed by drying, to the great injury of the plant. This danger may be eliminated by bedding the pots to the rim in a well-drained bed of sand or by setting the pot in another pot of 2 to 4 inches greater diameter, with a packing of moist sphagnum moss between and broken crocks at the bottom. (See Pl. XII, fig. 1.)

A burning of the young leaves and growing tips of twigs is often produced by the hot sun from the middle of June to the middle of September. Plants in pots or nursery beds are easily protected from such injury and forced to their maximum growth by a half-shade covering of slats, the slats and the spaces between being of the same width. On cloudy days the shade should be removed. It should not be used in the fall or spring.

During the winter the rooted cuttings, or 1-year-old plants, should be kept outdoors, exposed to freezing temperatures, their soil mulched with leaves, preferably oak leaves. When kept in a warm greenhouse during the winter they make no growth before spring. Even then their growth is abnormal, often feeble, or sometimes deferred for a whole year.

FIELD PLANTING.

Plants from cuttings or rooted shoots are ready for permanent field planting when they are 1 or 2 years old and 6 to 18 inches high. (See Pl. XII, fig. 2.)

It is a curious fact that these plants send out no new roots in spring until they are in full leaf, when their flowering is nearly or

quite finished and their principal twig growth has ceased. It is important, therefore, in taking up either a wild or a cultivated plant from the open ground that as much as possible of the old root mat be carefully lifted with the plant, for upon this the plants depend for moisture until their new rootlets are formed.

In the case of mature wild bushes with very large root systems, when it is practicable to secure but a fraction of the root mat, say a disk only 3 or 4 feet in diameter, it is the best procedure to cut all the stems at the time of transplanting to stumps 1 to 2 inches high. The bush will then produce a new and symmetrical top of a size suited to the capacity of the roots. The wood that is removed may be used for cuttings if the plant is sufficiently valuable.

The stems that make up a bush usually develop fibrous roots on their basal portions beneath the surface of the soil and above the root crown, at which the several stems unite. Such plants can be divided into several when taken up for transplanting. As many as 30 plants, each cut to a stump and with its own small but sufficient portion of the root mat, have been secured in this way from a large wild plant. By utilizing the various methods of propagation described in this publication as many as 600 cuttings of roots, stems, and twigs have been made from a single very large wild bush.

In resetting plants from which the tops have been removed, the stumps should be made to project about an inch above the surface of the ground. New shoots are formed in spring from such exposed stumps much earlier than from stumps covered with soil and not receiving the warmth of the sun's direct rays. If the plant when reset is made to occupy a moderate depression in the ground, the old stump and the bases of the new stems can afterward be covered with soil and a new root system will finally develop from the new wood.

When blueberry plants are set out in early spring, before the buds have begun to push, they usually make excellent growth, and for all plants that are pruned to the stump early spring is the best season for transplanting.

Conditions with unpruned plants, however, are different. Since blueberry plants make no new root growth until late spring, it often happens that a period of hot days intervenes between planting and rooting, and many plants are injured by an excessive loss of water before they have had time to make connection with the water supply of the surrounding soil through the development of new roots. The danger of such injury is greatest in the case of plants transplanted from pots. The old root ball sends up most of its water to the leaves, and in consequence, being at first, as a rule, in imperfect capillary contact with the new outside soil, the root ball commonly contracts slightly. The contraction is often sufficient to put the roots at the surface of the root ball permanently out of contact with the surrounding soil, and the plant may continue to suffer severely from

drought, although the soil outside the root ball contains plenty of moisture.

An early autumn field planting has furnished a remarkably successful means of avoiding this trouble with potted plants. At this season the excessive heat of summer is over, the plants are in full and vigorous leaf, and, being taken from pots, carry their whole root system with them. The formation of new roots begins at once and proceeds with great activity until the leaves are shed, at the approach of winter. In the spring, when new leaf growth begins, the plants are already well rooted in the soil. They pass through the early hot period without injury and develop remarkable size and vigor by autumn.

In preparing for a field plantation one precaution of special importance must not be overlooked. For the production of a crop of fruit under field conditions, insects are required to carry pollen from one flower to another. The honeybee works little on blueberry flowers. Her tongue is so short that she can not easily reach the nectar. The flowers are pollinated chiefly by bumblebees, whose tongues are long, and by some of the solitary wild bees that are small enough to crawl through the narrow opening of the corolla. When blueberry flowers are pollinated with pollen from their own bush the berries are fewer, smaller, and later in maturing than when the pollen comes from another bush. Some bushes are almost completely sterile to their own pollen. (See Pl. XIII.) The pollen of a plant grown from a cutting is likewise unsatisfactory for the pollination of the parent plant or of other plants grown from cuttings of it. It is important, therefore, that a plantation should not be made up wholly from cuttings from one bush. Two stocks should be used, a row of plants from one stock being followed by a row from the other.

In the permanent field plantation the bushes should be set 8 feet apart each way. When they reach mature size they will nearly or quite cover the intervening spaces.

When blueberry culture is to be tried in a sandy or gravelly soil deficient in peat or peatlike matter, the plants should be set in separate holes or trenches about 12 inches deep in a mixture of two to four parts of peat or half-rotted oak leaves to one part of clean sand. The excavations should be wide enough to provide ample space for new growth of the roots, not less than a foot each way from the old root ball. In small plantings, if the materials for the mixture are easily available in quantity, an 8-inch bed of it may be laid down over the whole surface of the ground, and if a planting is to be tried on a soil wholly unsuited to the blueberry, the area may first be covered with a 6-inch layer of sand, the bed of peat and sand mixture being then laid down on top of the sand layer. Wherever used, the peat and sand mixture should be thoroughly manipulated, so as to

give it a uniform texture before the plants are set out in it, for in a soil in which layers of peat alternate with layers of sand the capillary connection of the two is usually imperfect, and a plant rooted in the peat may suffer severely from drought, although the neighboring sand still has water to spare. For a similar reason it is important that when the plant is first set out, the peat and sand mixture shall be very tightly pressed and packed about all sides of the old root ball.

To secure full vigor of growth the ground between the bushes must be kept free from all other vegetation. On rocky uplands or in situations deficient in peat a continuous mulch of oak leaves, when it is practicable to secure them, will help toward this end, as well as keep the soil in the necessary acid condition. It is more economical, however, to choose such a location for the plantation as will permit the use of horse-drawn machinery and will make mulching unnecessary.

The most favorable location for blueberry culture is a moist area with a peat covering and sand subsoil, the peat preferably of such a thickness that deep plowing will turn up some of the underlying sand.

The land should be so ditched that the water level can be kept at least a foot below the surface of the ground during the growing season.

The ground should be plowed to the depth of about 8 inches and repeatedly harrowed or otherwise tilled during the season preceding the planting, in order to kill the wild vegetation. The best time for such plowing is late spring, after the principal vegetation has used up its winter store of starch in completing its early growth and before the leaves have matured and the roots have begun the new storage of starch with which they can send up new sprouts.

The tillage of the plantation after the young bushes have been set out should be sufficiently thorough to keep down all competing vegetation. This is best done by horse cultivation, with careful hand hoeing and hand weeding close about the plants. As the bushes grow older and their roots extend into the spaces between the rows, they develop root mats close beneath the surface of the soil. The tillage over these root mats should be very shallow, not more than 2 or 3 inches. This is probably best accomplished by the use of a small, light spring-tooth cultivator with the teeth set closer together than usual.

In case of drought, the drainage ditches may be used to bring in water for subirrigation. But unless the surface of the ground is very level, subirrigation is likely to result in the injury of plants in the lower spots by excess of water. In uneven areas, therefore, surface irrigation, if accompanied by good drainage, is preferable to subirrigation and should be used if practicable.

Fertilizer experiments have shown that lime is positively injurious to blueberry plants and that stable manure, while producing a

temporary stimulation of vegetative growth, is likely to cause serious injury later. For those desiring to experiment with fertilizers the following acid mixture is recommended, applied at the rate of 1,000 pounds per acre, or one-fifth of a pound per square yard:

	Pounds.
Acid phosphate (high grade, about 16 per cent available phosphoric acid)-----	600
Sulphate of potash (50 per cent potash)-----	200
Sulphate of ammonia (20 per cent nitrogen)-----	200
(Muriate of potash may be substituted for sulphate of potash.)	

This and similar acid mixtures have been used with success on blueberry plants in both pot and field experiments, with no evidence thus far of cumulative injurious effects. However, as no fertilizer is required to make the swamp blueberry fruit abundantly and continuously in suitable peat and sand soils properly handled, the use of fertilizers in commercial plantations is not at present advocated.

The swamp blueberry does not require a yearly pruning. When one of the stems of a bush becomes unproductive from injury or old age it should, of course, be cut out. If a large part of a bush needs removal it is better to cut all the stems to the ground and let the plant send up new shoots, all of the same age, to form a wholly new and symmetrical top.

YIELD AND PROFITS.

By proper manipulation in the greenhouse, seedling blueberry plants can often be made to ripen a few berries in less than a year, but they do not come into commercial bearing in field plantations until they are 3 to 4 years old (Pls. XIV, XV, XVI), when the plants are 1 to 3 feet high. They then increase slowly to full size and full bearing. Wild bushes of the swamp blueberry live to great age, often 50 to 100 years, still bearing heavily, and they often attain a height of 6 to 8 feet when growing in full sunlight; still more when shaded. Individual stems may remain productive for 10 to 25 years. When dead they are replaced by new and vigorous shoots from the root.

The field plantings resulting from the recent experiments in blueberry culture are too young to show the mature yield. Fortunately however, there is, near Elkhart, Ind., a small blueberry planting of mature age. The returns from this plantation set forward our knowledge of yields by at least a decade. The plantation is about $2\frac{1}{2}$ acres in extent. It was started in 1889 in a natural blueberry bog, which was first drained and then set with unselected wild-blueberry bushes. The plantation was profitable from the first, but exact records of yield and receipts are available only for the years 1910 to 1915, when the plantation was 21 to 26 years old. The data are shown in Table I.

TABLE I.—*Yield and receipts from a plantation of blueberries near Elkhart, Ind., 1910 to 1915, inclusive.*

Year.	Yield per acre.	Price (ap- proximate average per quart).	Receipts per acre.	Profits per acre.
1910 (a year of "almost total failure" because of late spring freezes).....	<i>Quarts.</i> 419	<i>Cents.</i> 17½	\$71.87	\$10
1911.....	2,266	12½	282.44	139
1912.....	2,379	12½	305.75	147
1913.....	1,770	15½	267.64	139
1914 (a year of severe midsummer drought).....	1,397	14½	201.94	92
1915.....	2,214	14½	321.00	170
Average for the 6 years.....	1,741	14½	243.44	116

The annual expenses for weeding, cultivation, and irrigation were about \$20 per acre. The cost of picking was 5 cents a quart. The general cost of maintenance of the equipment was about \$2 per acre per year, the crates and boxes being used repeatedly. The computation includes an estimated annual charge of \$12 per acre for interest, \$2 for taxes, and \$4 for depreciation or sinking fund.

It must be borne in mind that these figures are based on the yields from wild bushes transplanted without selection as to individual productiveness or the size of the berries. With bushes propagated from selected varieties, the yield should be greater and the berries much larger, this greater size probably effecting a reduction in the cost of picking and certainly an increase in the selling price.

Only a beginning has been made in the improvement of the blueberry. In a series of experiments involving the selection of superior wild strains, the growing of hybrids, and the forcing of choice varieties to quick fruiting by budding them on strong seedling stocks, berries seven-eighths of an inch in diameter have already been produced in the greenhouse. The yield and profits from such bushes in field plantations are not yet known. (For an illustration of a cluster of very large berries, see Pl. XVII.)

CONCLUSION.

The introduction of the blueberry into agriculture has a much more profound significance than the mere addition of one more agricultural industry to those already in existence. Blueberries thrive best in soils so acid as to be considered worthless for ordinary agricultural purposes. Blueberry culture, therefore, not only promises to add to the general welfare through the utilization of land almost valueless otherwise, but it offers a profitable industry to individual landowners in districts in which general agricultural conditions are especially hard and unpromising, and it suggests the possibility of the further utilization of such lands by means of other crops adapted to acid conditions.¹

¹ For a discussion of the principles of acid-soil agriculture in districts in which the cost of lime is prohibitory, consult "The Agricultural Utilization of Acid Lands by Means of Acid-Tolerant Crops," United States Department of Agriculture, Bulletin No. 6, 1913.



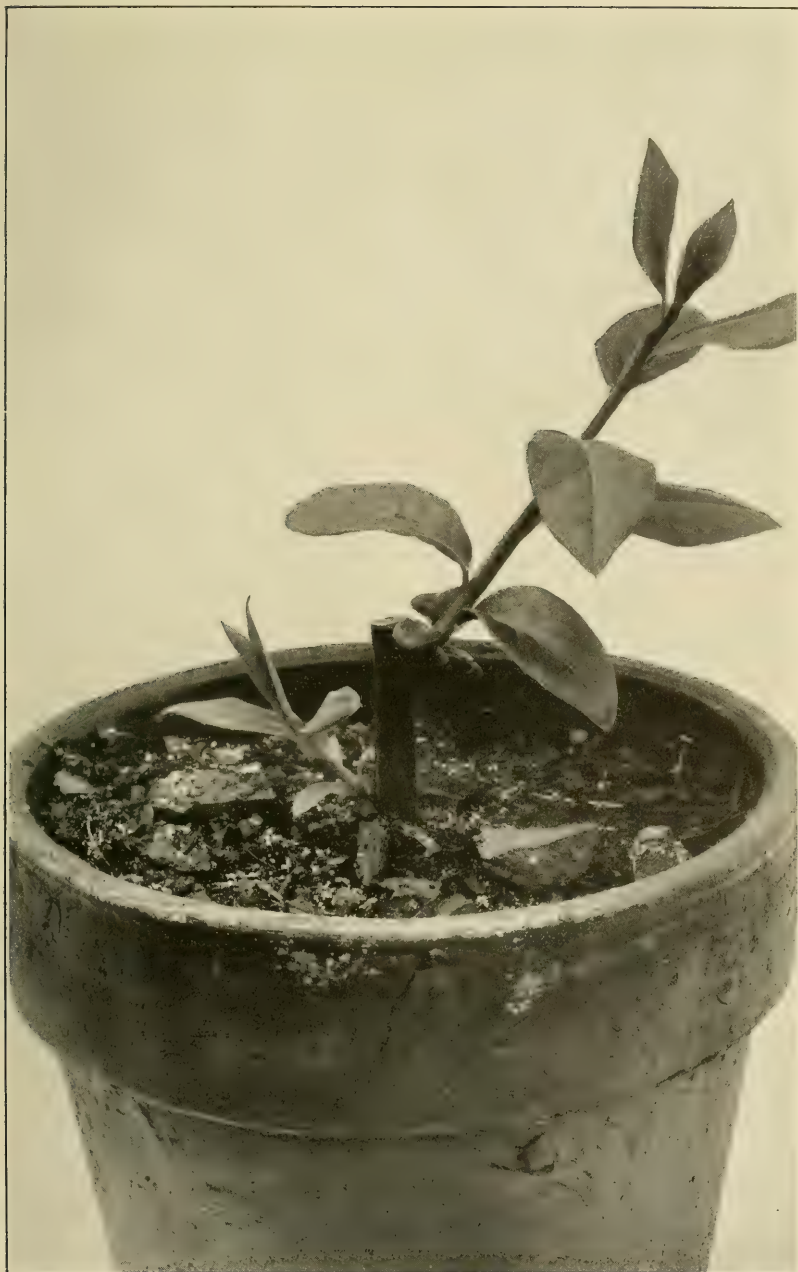
BLUEBERRY PLANTS SHOWING THE EFFECT OF ACID SOIL AS CONTRASTED WITH RICH GARDEN SOIL.

The three large 1-year-old blueberry plants were grown in a greenhouse in a peat soil. All three are over 24 inches high, the one at the left 27 inches. Standing on the middle pot is a small glass pot containing a seedling of the same age and origin as the others but potted in a rich garden soil. The difference in results shows the fundamental importance of a peaty acid soil for blueberry culture. (One-eighth natural size.)



NEW SHOOTS ON A STUMPED BLUEBERRY PLANT.

The three shoots shown grew after the plant had been cut to the stump. Their white color at the base indicates the depth of the propagating bed through which they forced their way and from which the plant was taken to be photographed. Roots had already begun to develop. (Natural size.)



BLUEBERRY PLANT FROM A ROOTED STUMP SHOOT.

The old cut-off stem shown in the illustration is the rooted base of a vigorous shoot from a stumped blueberry. It was removed from the parent plant a year after stumping, was potted in a 4-inch pot, and when photographed was in process of developing two new leafy branches. (Natural size.)

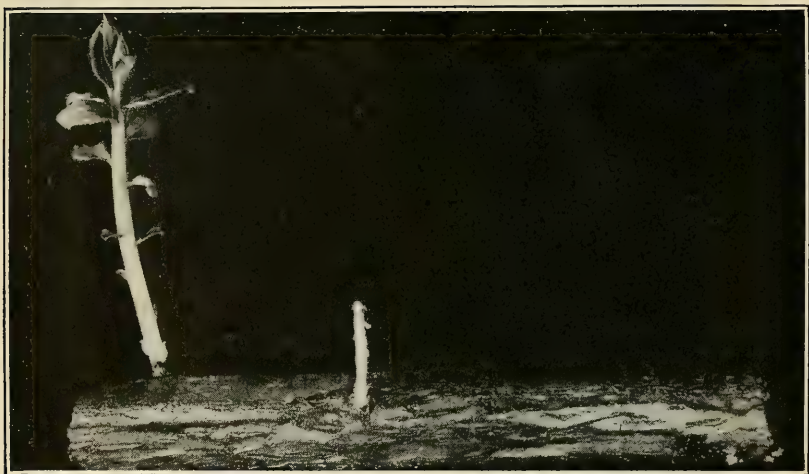


FIG. 1.—TUBERED BLUEBERRY CUTTING WITH YOUNG SPROUTS DEVELOPING.



FIG. 2.—TUBERED BLUEBERRY CUTTING WITH SPROUTS ROOTING AT THE BASE.

The sprout at the left in figure 1 had emerged from the sand and begun to develop green leaves above the surface. The sprout near the center of figure 1 is younger, the whole of it still in the rootstock stage. The two sprouts in figure 2 are developing roots on their lower parts, above the dying wood of the old cutting and beneath the surface of the cutting bed. (Both natural size.)



WELL-ROOTED SPROUTS FROM A TUBERED BLUEBERRY CUTTING.

Sprouts with roots thus far developed are ready for potting, even though secondary growth, as in this case, has not yet taken place. These two sprouts are so closely united that they can not safely be separated into two plants. (Natural size.)



NEWLY POTTED BLUEBERRY PLANT FROM A TUBERED CUTTING.

After the sprout from the tuberous cutting had rooted and before it was potted it had made secondary growth from the tip of the original sprout. (Natural size.)



FIG. 1.—BLUEBERRY PROPAGATION SHELTER AT WHITESBOG, N. J.

The illustration shows the north and west sides of the shelter and the fence surrounding it. The shelter covers four rows of frames, which face south. Each of the four sections is 9 feet high and 10 feet 10 inches from front to back.



FIG. 2.—BLUEBERRY PROPAGATION FRAMES AT WHITESBOG, N. J.

Each sash is of the standard size, 3 feet wide and 6 feet long. The wooden sides of the cold-frames rise 2 feet from the ground at the back and 1 foot at the front. The lowest part of the roof joists is 6½ feet above the ground.



BLUEBERRY CUTTINGS IN EARLY STAGES OF GROWTH.

The figure at the left shows a cutting callused at the base and the uppermost bud pushing, but the green bracts and young leaves not yet expanded. In the middle and right-hand figures callusing has proceeded farther at the cut surfaces, both top and bottom, and the formation of new leafy twigs is well under way; but the growth of the tips has not yet been terminated. As shown in the right-hand figure, twigs are often produced from two of the upper buds, sometimes more. (Natural size.)



FIG. 1.—BOX OF BLUEBERRY CUTTINGS AFTER MULCHING.

The box is 10 by 12 inches by 8 inches deep, inside measurement. The new twigs have completed their primary growth, their leaves have reached full size, and the formation of roots is about to begin. Secondary twig growth has not yet taken place.



FIG. 2.—BOX OF BLUEBERRY CUTTINGS SHOWING SECONDARY GROWTH.

Most of the cuttings have put out and matured their strong secondary twigs. This condition of twig growth is conclusive evidence that the cuttings are well rooted and that the box is ready for ventilation.



WELL-ROOTED BLUEBERRY CUTTING.

This cutting with the sand adhering to it has just been removed from its cutting bed. The illustration shows the secondary twig growth that took place from the apex of the primary twig after the cutting had begun to form roots. The dark-colored bud scales just below the middle of the leaf-bearing axis mark the apex of the primary growth and the base of the secondary growth. This cutting was in the cutting bed from February 3 to August 6, when the photograph was taken. Under greenhouse propagation the cutting is ready for potting; under outdoor propagation it should remain in the cutting bed until late autumn or early spring. (Natural size.)



BLUEBERRY PLANTS FROM ROOT CUTTINGS.

The illustration, from a photograph taken on July 27, shows the excellent growth secured from root cuttings buried in a coldframe cutting bed early in the spring of the same year. This section of the coldframe is of the size of a standard sash, 3 feet in width and 6 feet from front to back.



FIG. 1.—DOUBLE-POTTED BLUEBERRY PLANT.

The plant shown in figure 1 is in a 4-inch pot, which is set in an outer 7-inch pot with a packing of moist sphagnum moss between. Rooted sprouts from tubercled cuttings which were potted in this manner developed in their second year an average stem length of 25 inches. The illustration is from a photograph of one of these plants. (About one-eighth natural size.) The photograph from which figure 2 was made was taken on November 14, after the plant had shed its leaves. Plants of this size and vigor are ready for the field plantation. (One-fourth natural size.)

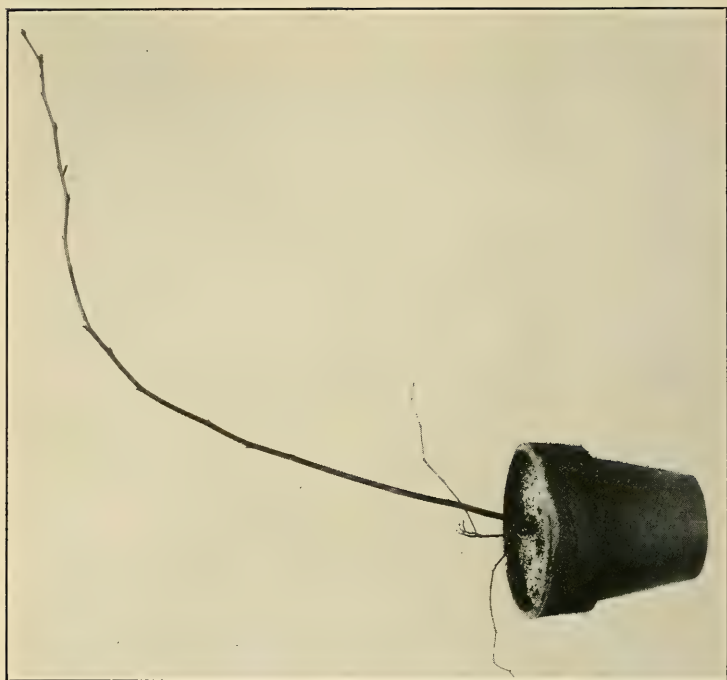
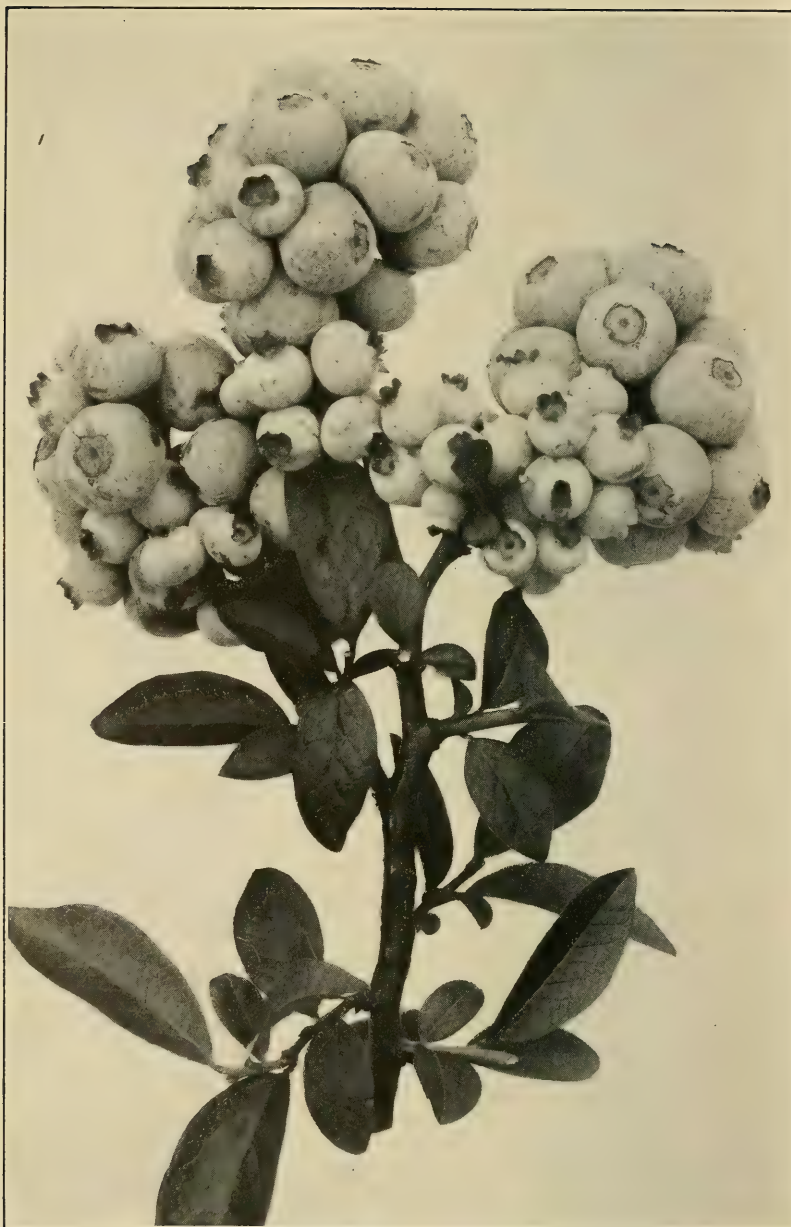


FIG. 2.—TWO-YEAR-OLD BLUEBERRY PLANT FROM A WINTER CUTTING.



EFFECT OF SELF-POLLINATION IN THE BLUEBERRY AS COMPARED WITH CROSS-POLLINATION.

These two twigs, both natural size, were in equally good situations on the same bush, contained the same number of flowers, all pollinated by hand at the same time with equal care, and the fruits were photographed on the same day. The only difference in treatment was that the pollen used on the left-hand twig came from other flowers on the same bush, while the pollen for the right-hand twig was taken from another bush. The cross-pollinated flowers produced a full cluster of handsome fruit. The self-pollinated flowers produced no ripe fruit, all the fruit that set remaining small and green and later dropping off, until at the time the photograph was taken only two such imperfect fruits remained. A plantation made up wholly from cuttings from a single bush would produce little or no fruit. At least two original propagation stocks are necessary.



CLUSTER OF BLUEBERRIES ON A 3-YEAR-OLD HYBRID.

This cluster of berries, which is of natural size, is from one of the hybrid bushes shown in Plate XV. The berries had a very light blue color, firm but juicy flesh, exceptionally delicious flavor, and seeds so small as not to be noticeable when the berries were eaten. The largest berry on this bush was 15 millimeters in diameter. Other bushes in the plantation bore berries 17 millimeters in diameter, larger than those of either parent. The small berries on the cluster were still green. Such berries increase rapidly in size during the few days of ripening.



FIG. 1.—THREE-YEAR-OLD BLUEBERRY PLANT IN COMMERCIAL BEARING.

This plant is a hybrid between two selected wild stocks, from Greenfield, N. H., and Brown Mills, N. J. They were hybridized in the greenhouses at Washington in the summer of 1912, and the hybrid seeds were sown September 9. The young plants were carried over winter in the greenhouse, and early in September, 1913, they were sent to Whitesbog, N. J., and set out in a trial field plantation. The photograph was taken July 27, 1915, when the plant was a little less than 3 years old. The plant is one of those shown in figure 2 (below). (About one-fifth natural size.)



FIG. 2.—PLANTATION OF 3-YEAR-OLD BLUEBERRY HYBRIDS AT WHITESBOG N. J.

These hybrids are of the same age and parentage and have received the same treatment as the plant shown in figure 1 (above). In the third year from the seed they produced their first commercial crop, valued at \$37 per acre, gross receipts. The rows are 5 feet apart and the plants 3 feet apart in the row, too close a spacing for a permanent plantation (which should be 8 by 8 feet) but correspondingly more productive in the earlier years.



FOUR-YEAR-OLD BLUEBERRY HYBRID.

This is one of a series of hybrids made in 1911 between selected wild plants of a low-bush blueberry (*Vaccinium angustifolium*) and a high-bush or swamp blueberry (*V. corymbosum*), both from Greenfield, N. H. The plants are now in the trial plantation at Whitesbog, N. J. They fruit much earlier in the year than the wild New Jersey swamp blueberry. The photograph was taken July 7, 1915. Some of the berries were ready to pick two weeks before that time. These 4-year-old hybrids yielded more than three times as large a crop as the 3-year-old hybrids shown in Plate XV. The best 4-year-old bush bore 2 quarts of berries. (About one-sixth natural size.)



HYBRID BLUEBERRIES OF LARGE SIZE.

These berries, shown in their natural size, reached a diameter of 18.6 millimeters, nearly three-quarters of an inch. They were produced in the greenhouses at Washington on a plant 12 months old, in a 4-inch pot. One of the parents of this hybrid was itself a selected hybrid, of selected high-bush and low-bush New Hampshire parentage, and the other parent was a selected wild swamp blueberry from New Jersey. It is not yet known what results these hybrids will yield in field plantations. Many thousand hybrids will be fruited in the trial plantation at Whitesbog in the pine barrens of New Jersey, and from these a few of the best bushes will be selected for final propagation and distribution.

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CARL L. ALSBERG, Chief



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DEVELOPMENT OF SUGAR AND ACID IN GRAPES DURING RIPENING.

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INTRODUCTION.

In Bulletin 140, Bureau of Chemistry, a preliminary report is made on the changes in sugar and acid content of several varieties of grapes as determined in 1909 and 1910 during a period of several weeks previous to ripening and at full maturity. The results of a further and more extended examination of several of these varieties of grapes made during the seasons of 1911 and 1912 are presented in this bulletin. The examinations were made at Sandusky, Ohio, and at Charlottesville, Va.

The period of observation and analysis of the fruit samples was considerably extended beyond that previously reported and more complete analyses were made so as to secure additional data covering several important questions, such as the presence of other acids than tartaric and the changes in the ratio of combined and free tartaric acid. The study of the increase of sugar content and the changes in total acid content remain, however, as heretofore, the prime object of the investigation.

Study of the fundamental changes which occur during the ripening of grapes is of importance in the determination of the normal compo-

sition of grape products, and it would appear that the data secured should have practical value to growers who wish to secure the highest quality of fruit; therefore the analytical results are presented quite fully.

CHANGES IN THE CHEMICAL COMPOSITION OF GRAPES DURING THE RIPENING PERIOD.

The ripeness of the grape should not be judged merely by its color, for many varieties color long before they are fully ripe. Ripeness can be properly determined only when both chemical composition and physiological condition are considered. Many of the varieties of grapes derived from native American species at present commercially grown show a rather high acidity. In such grapes the qualities desired are the highest content of sugar and the lowest content of acid which can be secured without deterioration of the marketable condition of the crop. Some exceptions to this statement may be noted, as, for instance, the Delaware, which, when fully ripe, shows an acid-sugar ratio too wide for dry wine manufacture.

In the ripening of grapes the increase of sugar and the elimination of acid are dependent upon many factors, such as climatic and soil conditions, the vigor of the plant, the site, pruning and training, and species and variety characteristics. With certain reservations, sugar should increase and acid diminish as long as the leaves function properly. This, however, is not always the case, for as soon as the pedicels—the small stems which carry the berries—begin to wither, the fruit is gradually cut off from further influence of the growth processes taking place in the plant, and its sugar content may remain fairly constant for some time. It may appear to increase by reason of evaporation of water from the berries, or in certain cases may seem to be reduced by changes induced by the respiratory processes of the fruit. The acid content is notably affected by respiration, especially if malic acid is present in any quantity.¹

The total sugar and acid content are not the sole factors of importance in determining the acceptability of the fruit for manufacturing purposes, because the total acid-reacting substances are composed of several substances, among which the malic acid is at times quite as important as the tartaric acid. The content of malic acid is of importance, because this acid is to a considerable extent eliminated by oxidation through respiratory processes during the development of the fruit.² As far as this process occurs it causes a positive lowering of the acid content of the juice. In wine making whatever portion of the malic acid remains free and goes into the young wine

¹ Babo und Mach, Weinbau, 3d ed., 1909, 1: 117, 157-159; Ibid, Kellerwirtschaft, 4th ed., 1910, 2: 12, 13, 31, 162.

² Ibid.

can be largely changed by after-fermentation into lactic acid and carbon dioxid,¹ thus still further lowering the acid content of the final product. This latter change in the malic acid can not, however, occur in juices that are used in unfermented condition, as bottled grape juices.

The occurrence of malic acid in the grape is very well known, yet it is difficult to determine the acid as such by the methods available in this laboratory; hence the acid substances here discussed as malic acid were not estimated by direct determination. These substances are in fact the fixed acids other than tartaric, but it is known that of these only malic acid² occurs in important quantities.

The total acidity of the fruit is also very sensibly lowered some seasons through the disappearance of free tartaric acid during ripening. It appears from our results that free tartaric acid in many cases entirely disappears in the ripe fruit, especially from those varieties with dark-colored juice. In some varieties with light-colored juice, like Catawba, the disappearance of free tartaric acid does not seem so complete, especially when the fruit ripens late.

The disappearance of free tartaric acid³ as the fruit matures is primarily due to the influx, into the developing fruit, of potassium, which combines with the free tartaric acid to form cream of tartar, the insoluble acid tartrate of potassium. This compound is present in all grape juices and its titratable acidity is but one-half that of the free tartaric acid before combination with the potassium, hence those conditions which encourage the formation of this acid salt sensibly reduce the acidity of the juice of the fruit. Other bases, such as lime and magnesia, also enter into combination with tartaric acid to form the alkaline-earth tartrates; but these salts occur only in slight quantities, and their presence does not materially affect the total acidity from the manufacturing standpoint. The formation of crystals of cream of tartar in the fruit, and the fact that these crystals occur in the pressed residue of freshly-crushed grapes, has been determined by the authors,⁴ but these phenomena require further study before their effect upon total acidity can be stated. The precipitation of this salt of tartaric acid, in whatever manner it may occur, has a marked effect upon the final acidity of food products made from grape juice. Thus a freshly-pressed grape juice or young wine will ordinarily show a decided precipitation of tartar or argol within a few months.

After the disappearance of all free tartaric acid any further influx of potassium or of other bases will result in a union with the malic

¹ Külisch, Weinverbesserung, 3d ed., 1909, p. 19.

² Babo und Mach, Kellerwirtschaft, 4th ed., 2: 12, 162-163.

³ Babo und Mach, Weinbau, 3d ed., 1909, 1: (1) 159-161, tables; Ibid, Kellerwirtschaft, 4th ed., 1910, 2: 13-14; Koenig, Nahrungs und Genussmittel, 4th ed., 1903, p. 1174.

⁴ J. Agr. Res., 1913, 1: 513.

acid to form malates of potassium, calcium, or magnesium. The formation of these salts would still further reduce the acidity of the juice.

There is a further consideration which enters into the relative acid content of green and ripe fruit—that of the dilution of the acidity by an increase of the sugar and water content. An attempt to determine the extent to which this change affects the percentage of acid content was undertaken in 1912 and is treated in a section of this report.

It appears, then, that there are a number of changes in the composition of the fruit during its development and ripening which tend to lower the acid content. Therefore, grapes which originally contained a high total acidity might in many cases mature so as to reduce the final acid content of products made from them. The prime points of consideration for wine making are that the fruit should be well ripened, so that all of the combinations of the bases with the acids which are possible may be carried to completion and that malic acid may be eliminated by growth processes to the fullest extent practicable. Then the cream of tartar in the expressed juice, whether it be used for unfermented fruit juice or for wine, should be precipitated as perfectly as possible. If malic acid is present in any quantity in wine it will be largely changed by after-fermentation into lactic acid, if proper conditions are observed.

Then a grape may be said, in a manufacturing sense, to be ready to harvest at that period in its development when the sugar content and the acid elements have reached the most favorable state (considering the purpose for which it is intended) that is possible for the variety in the particular season, location, and other prevailing conditions.

SOURCES AND PREPARATION OF SAMPLES.

During the years 1911 and 1912 a certain number of plants of each variety investigated were reserved for the samples desired. These plants were selected with a view of guarding a quantity of average fruit so that the sampling might be done in a manner to secure typical material. The work of this laboratory on grape samples during the past four years has shown that it is not possible to select two samples of fruit at the same time which shall be exact duplicates. It is also true that one can not select samples from the same vines at different dates which will give results entirely logical in the sequence of the changing constituents. The analyses herein reported show the effect of these variations in sample, but these are not such as to confuse the results.

The 1911 samples of Catawba, Delaware, Ives, and Norton, examined at Sandusky, Ohio, were taken from a vineyard at Venice, about 3 miles west of Sandusky. The soil is heavy black loam over-

lying limestone. The land is flat and only a few hundred yards from the shore of Lake Erie. The 1911 samples of Clinton were taken from a neighboring vineyard on similar soil. These samples were collected in every instance by J. R. Eoff, who was in charge of the chemical examinations at Sandusky.

The 1911 samples of Concord, Delaware, and Norton at Charlottesville, Va., were taken from a vineyard of which the soil is the characteristic Piedmont red clay, lying on a slope just below an outcrop of gray sandstone. The Cynthiana samples were taken from another vineyard situated on soil of like character. These samples were taken in every instance by William B. Alwood or B. G. Hartmann.

During 1912 fewer varieties were examined than previously, but the amount of work done was extended to cover points not before investigated. At Sandusky only Concord and Catawba were examined, and these were obtained from the vineyard first described. At Charlottesville, Concord and Delaware were examined, both from the vineyard which had supplied samples of these varieties the previous year.

For all examinations of whatever nature about 5 pounds of fruit were selected in the vineyard and the bunches were placed in a small fruit basket and stored uncovered in the cellar of the laboratory for 18 to 24 hours at a temperature of about 60° F. The purpose of holding the fruit in the cellar was to bring all samples to as nearly as possible the same temperature before crushing, so that the results for cream of tartar should not be affected by reason of the variation in its solubility at different temperatures.

The fruit used for juice samples was brought from the cellar and crushed at once by hand in porcelain-lined vessels. About 2 pounds of unstemmed fruit were used and care was observed to take average quality as to ripeness. The berries were carefully pulped with the fingers until well broken up, then the juice was expressed through a double thickness of cheesecloth, working the pulp into a ball in the cloth and applying such pressure as experience has shown will ordinarily extract the juice as efficiently as when freshly pulped fruit is pressed on a power press at 1,500 pounds direct pressure. The juice recovered was strained by filtering through cotton, and from this portion the chemical sample was taken. A Brix reading was then made at 20° C. on the fresh juice. Then 250 cc of the sample, the quantity desired for analysis, were measured and diluted with an equal volume of distilled water, thus giving 500 cc. This diluted sample was filtered through paper and a 20 cc portion titrated for total acid; the specific gravity was determined at once in a pycnometer. During 1912 the specific-gravity determinations were made in a pycnometer on the undiluted juice. The further determi-

nations were made as far as possible on the same day, or at least the manipulation was carried to a point where any change in composition would not affect the determination. All the determinations were completed within 36 hours after crushing the fruit.

Diluting the samples keeps the juice more nearly normal, preventing precipitation of tartar, which may occur if the sample should stand for some hours. The diluted sample can be filtered much more readily than the undiluted juice, and in case of colored juices a clearer end point is obtained when the sample is titrated for acidity.

While the analyses made in 1912 were confined to three varieties, the work was extended to include complete analyses of the fruit of two varieties, as well as the analyses of the juice samples as heretofore made. First, an analysis of the juice sample was made in the manner detailed for 1911, and the results for 1912 are in all respects comparable with the data for that year, save that the total tartaric acid for 1912 was obtained by the method of half neutralization proposed by Hartmann and Eoff.¹

It is evident that the analysis of a juice sample does not furnish final data on the composition of the entire fruit, because it is impossible to secure, by crushing and pressing a sample of the fruit, all of the constituents of the berries. This method secures only such as are in solution in the juice sample recovered. While the results for many constituents when the juice and whole-fruit sample are compared are somewhat similar, there are some important variations.

For the sample for whole fruit analyses in 1912, taken at the same time and from the same fruit selected for the juice sample, the berries were carefully clipped with sharp scissors from the stems at the junction of the fruit with the pedicels, care being taken not to break the skin of the fruit. A sample of 800 to 1,000 grams was prepared in this manner. The berries were held in a large piece of cheese-cloth and rolled to and fro until they were thoroughly mixed, then from different portions of the mass two samples of 100 grams each were taken for duplicate determinations of the organic constituents, and three samples of 100 berries each for triplicate weighings and measurements of volume of the fruit. The several samples required for burning direct to secure the ash samples were also taken at this time.

The samples for the organic determinations were exhausted in distilled water as follows: Each was placed in a cheese-cloth square and tied firmly with twine, so that the fruit was confined in a ball. These were suspended in 500 cc beakers containing about 200 cc of distilled water, placed over a flame, and kept constantly at boiling temperature. After 10 to 20 minutes the water containing the solution extracted from the fruit was removed to a large porcelain

¹ U. S. Dept. Agr., Bur. Chem., Bul. 162, pp. 71-77.

evaporating dish and replaced with hot distilled water. This exhaustion was repeated five or six times and the solution collected in the porcelain dish. When the extraction seemed complete, cold distilled water was added to the beaker. The pulp in the cloth was then carefully worked and pressed with the fingers to extract the remainder of the soluble constituents, which was added to the extract already collected. To determine whether the exhaustion was complete the pomace in the cloth was again treated with boiling water and a 10 cc portion titrated with tenth-normal sodium hydroxid, using phenolphthalein as indicator. If not more than 0.5 cc of tenth-normal sodium hydroxid were required to neutralize the portion taken, exhaustion was considered complete. If the material still showed appreciable acid the extraction with water was continued until complete.

The solution collected from the successive boilings, after being kept on a water bath until the volume was sufficiently reduced, was transferred to a 500 cc graduated flask. The porcelain dish was carefully rubbed with a policeman and rinsed with hot water until all the extractive matter was recovered. The solution was cooled to room temperature and made up to 500 cc, and from this sample all the organic determinations were made. The fruit samples were treated in duplicate by this method and the results checked satisfactorily. The average result of these two determinations, in percentage of the weighed fruit sample, is given in Table 6.

In order to determine more accurately the inorganic constituents, such as phosphoric acid, chlorin, potassium oxid, sodium oxid, calcium oxid, and magnesium oxid, weighed portions of the same fruit sample were ashed direct for these determinations. An attempt was made to use the solution extract for the determination of chlorin, but it was found by check determinations that this solution gave a large excess of chlorin, indicating that chlorin was probably introduced in some manner during the preparation of the solution. The fruit for these determinations was ashed in platinum dishes in the usual manner, 50 to 80 gram samples being used. The results are given in percentage of the weighed sample.

METHODS OF ANALYSIS.

The official methods for wine (Bureau of Chemistry Bulletin 107, Revised) were followed in the work done during 1911, save for cream of tartar, free tartaric acid, tartaric acid to alkaline earths, and for the item reported as fixed acid other than tartaric. For determining these substances, except the last named, the revised methods given (Bureau of Chemistry Bulletin 162, pages 71 to 77) were followed, and in the results reported for 1912 the total tartaric acid was determined by the revised method given in this bulletin. These

methods have been carefully checked in this laboratory and at the Bureau of Chemistry and found to give more reliable results than the methods given in Bureau of Chemistry Bulletin 107, Revised. For the items reported as "Fixed acid other than tartaric," the following formula was used: Total acid as tartaric—[(total alkalinity $\times 0.0075$) + free tartaric acid]=fixed acid other than tartaric expressed as tartaric. This result is practically the same as the "Sauerrest" of the German chemists.¹

This formula gives those acids present other than tartaric, but as it is known that almost the total quantity of these acids in the grape consists of malic acid,² the result may be interpreted as this acid for the considerations involved in this report. To actually convert this result to malic acid, multiply the figures given in the table by 0.8934. It was not possible, with the conditions under which this work was done, to determine the minute quantities of other acids present, such as succinic and glycolic acids.

The total acid percentage is practically the same in the green fruit of Concord in both juice and whole-fruit samples, and this relation continues so nearly throughout the entire period that either result may be taken as fairly expressing the content. The total acid is decidedly higher in the juice sample of green Catawba than in the whole fruit for the first three samples taken; then the acid content of both samples becomes about what may be expected of check samples.

The results for total tartaric acid in the juice and whole fruit are not so uniform as for total acid. Yet for the Concord samples, both at Sandusky and Charlottesville, there is a degree of uniformity which is striking, considering the difficulty of sampling which has been mentioned. The Catawba samples show much difference in the green fruit, but the later samples approach uniformity.

There is a striking dissimilarity in the percentage of tartaric acid for the Concord samples at Sandusky and Charlottesville throughout the period of investigation. Those taken at Sandusky show much less variation than the Charlottesville samples and the former show approximately the same amount at the close of the season as for the partly colored samples first taken, while the Charlottesville samples show a very marked decline in tartaric acid for both the juice and fruit samples. Further investigation of this point is necessary before offering any critical discussion.

It would appear that the crushed fruit invariably yields decidedly the greater part of the free tartaric acid content when pressed. The rapid diminution of the percentage of this acid as the fruit ripens is shown for both the juice and fruit samples. These results support

¹ Babo and Mach, *Kellerwirtschaft*, 4th ed., 1910, 2: 629.

² Babo and Mach, *Weinbau and Kellerwirtschaft*, loc. cit.

our previous determinations and show that the Concord juice loses free tartaric acid more completely than the Catawba.

The results for cream of tartar show that in every instance save one the juice sample carries a smaller percentage of cream of tartar than the whole fruit. The one exception, No. 3588, is affected by an evident error and is excluded from consideration. The excess, in per cent, of cream of tartar in the whole fruit is sufficient to support a previous statement that this substance exists as crystals and that some of these are retained in the pulp when the fruit is pressed.

The constant increase of cream of tartar both in the juice and fruit samples follows naturally from the disappearance of free tartaric acid. The results for 1912 are in this respect more logical than those for 1911.

The data given under fixed acids other than tartaric are considered by the authors to be remarkably interesting. It is shown that the total content of tartaric acid remains nearly constant, especially when the whole fruit samples are compared, but these other acids, which we have considered as mostly malic, show such a steady and sharp decline that one is forced to accept conclusions derived from the data given in Table 5. The reduction in the percentage of acid under this head reaches two-thirds to three-fourths of the entire amount given for the first samples taken.

ANALYTICAL RESULTS ON THE JUICE SAMPLES.

CROP OF 1911.

In Table 1 the condition of the fruit on the vines at the time of sampling and the results of the analyses of samples both at the Sandusky and Charlottesville laboratories are given in detail. The period covered by the analyses at Sandusky was carried beyond the wine-ripe condition, except in the case of the Norton, which was destroyed by the berry moth¹ before it was fully ripe. This continuation of the analyses was for the purpose of following the changes that occur in the fruit even to the natural destruction of the crop. The high temperature of the fall season at Charlottesville is not favorable to holding samples at that point after they are fully ripe, hence the data for that locality cover only the period to full maturity.

¹ *Polychrosis viteana* Clemens.

TABLE 1.—*Analyses of grapes at different dates during maturity.*

[Results in grams per 100 cc.]

1911 SAMPLES FROM SANDUSKY, OHIO (COFF AND SHERWOOD, ANALYSTS).

Variety and laboratory number of sample.	Date analyzed.	Condition of fruit.	Specific gravity.	Total solids.	Sugar-free solids.	Total sugar as invert.	Total acid as tartaric.	Total tartaric acid and tartarates.	Free tartaric acid.	Fixed acid other than tartaric.	Cream of tartar.	Tartaric acid to alkaline earths.	Tannin.	Crude ash.	Alkalinity of ash expressed in cubic centimeters of tenth-normal hydrochloric acid.		
															Total.	Water-soluble.	Water-insoluble.
Catawba:																	
3037.....	Aug. 13	Large bunches, berries green.....	1.0322	8.33	5.84	2.49	4.29	1.34	0.57	3.33	0.74	0.18	0.076	0.35	51.6	39.6	12.0
3042.....	Aug. 16	do.....	1.0389	10.03	5.30	4.76	3.86	1.01	.28	3.21	.69	.18	.042	.33	48.7	36.6	12.1
3047.....	Aug. 20	Large bunches, show slight pink color.....	1.0471	12.19	4.97	7.22	3.35	.98	.22	2.75	.75	.16	.017	.37	50.8	40.0	10.8
3052.....	Aug. 23	do.....	1.0539	13.96	4.50	9.46	2.96	1.01	.22	2.35	.80	.15	.028	.39	52.4	42.4	10.0
3058.....	Aug. 27	Large bunches, berries colored.....	1.0489	15.27	3.69	11.58	2.21	.79	.15	1.74	.65	.11	.017	.32	42.4	34.8	7.6
3064.....	Aug. 30	do.....	1.0613	13.89	3.57	12.32	1.93	.74	.08	1.57	.67	.12	.017	.32	43.6	35.6	8.0
3071.....	Sept. 3	do.....	1.0711	13.45	3.21	13.24	1.50	.59	.03	1.18	.53	.12	.017	.26	36.0	28.0	8.0
3079.....	Sept. 6	do.....	1.0736	19.10	3.02	16.08	1.28	.53	.03	1.00	.48	.12	.017	.23	33.6	25.6	8.0
3101.....	Sept. 10	do.....	1.0740	19.21	2.93	16.28	1.19	.57	.03	.81	.37	.08	.021	.23	23.2	19.6	5.6
3110.....	Sept. 13	Flavor shows ripening.....	1.0773	20.07	2.79	17.28	1.12	.60	.03	.78	.30	.11	.021	.23	34.4	26.8	7.6
3130.....	Sept. 17	Color becoming dark.....	1.0858	20.96	3.00	17.96	1.05	.51	.00	.79	.55	.07	.024	.26	34.8	29.2	5.6
3146.....	Sept. 20	do.....	1.0854	22.30	2.86	19.44	.99	.48	.00	.73	.53	.05	.012	.25	34.4	28.4	6.0
3177.....	Sept. 24	do.....	1.0884	22.99	3.05	19.94	1.06	.57	.00	.75	.62	.07	.014	.31	40.8	33.2	7.6
3199.....	Sept. 27	do.....	1.0880	22.88	2.94	19.94	.99	.50	.00	.63	.53	.08	.017	.28	34.0	28.0	6.0
3219.....	Oct. 1	Began picking for wine.....	1.0850	22.09	3.18	18.92	.95	.54	.00	.71	.57	.08	.021	.30	37.6	30.0	7.2
3243.....	Oct. 4	Condition good, ripe.....	1.0850	22.25	2.80	19.45	.95	.58	.04	.64	.56	.10	.015	.27	36.4	30.0	6.4
3254.....	Oct. 8	do.....	1.0839	21.80	3.23	18.57	.94	.64	.05	.59	.62	.10	.029	.32	39.6	32.8	6.8
3283.....	Oct. 15	Still picking for wine.....	1.0838	21.52	3.22	18.30	1.04	.63	.00	.70	.73	.14	.036	.37	46.0	38.8	7.2
3297.....	Oct. 18	Condition good, ripe.....	1.0860	22.36	2.88	19.48	.89	.67	.06	.52	.64	.10	.036	.34	40.8	34.0	6.8
3307.....	Oct. 22	Fruit dropping slightly.....	1.0863	22.43	2.62	19.81	.80	.62	.06	.47	.57	.10	.024	.30	37.2	30.4	6.8
3314.....	Oct. 25	Fruit dropping badly.....	1.0860	22.43	2.94	19.49	.86	.66	.17	.44	.49	.10	.031	.31	32.4	26.0	6.4
3326.....	Oct. 29	Heavy frost, fruit dropping badly.....	1.0890	23.14	2.47	20.67	.71	.53	.03	.44	.50	.10	.028	.27	33.2	26.4	6.8
Clinton:																	
3034.....	Aug. 13	Bunches large, more than 90 per cent colored.....	1.0684	17.75	5.53	12.22	2.95	1.46	.26	2.09	1.16	.29	.07	.60	79.8	61.9	17.9
3039.....	Aug. 16	do.....	1.0539	13.96	5.14	8.82	2.89	1.46	.37	1.97	1.04	.26	.02	.54	72.5	55.2	17.3
3044.....	Aug. 20	do.....	1.0636	16.49	4.44	12.00	2.47	1.19	.28	1.74	.93	.17	.03	.48	68.0	49.2	11.6
3049.....	Aug. 23	Bunches large, all colored.....	1.0781	20.28	4.73	15.55	2.28	1.27	.25	1.52	1.02	.21	.07	.54	68.0	54.0	14.0
3055.....	Aug. 27	Bunches large, taste shows ripening.....	1.0783	20.34	4.17	16.17	2.03	1.21	.22	1.32	1.04	.16	.07	.53	66.0	55.2	10.8

3061....	Aug. 30	Slight rot, full color.	1.0831	21.59	4.40	17.19	2.02	1.25	.21	1.29	1.07	.18	.07	.56	68.8	56.8	12.0
3068....	Sept. 3	Fruit condition good, ripening.	1.0904	22.51	4.14	19.03	1.90	1.27	.24	1.15	1.05	.19	.07	.56	68.4	56.0	12.4
3076....	Sept. 6	Fruit condition good, leaves falling.	1.0876	23.78	4.77	18.01	1.99	1.39	.19	1.20	1.23	.23	.11	.61	80.4	65.2	15.2
3098....	Sept. 10	Fruit condition good, ripening slowly.	1.0904	23.51	4.14	19.37	1.67	1.13	.25	.98	.87	.19	.10	.54	58.8	46.4	12.4
3107....	Sept. 13	do.	1.0870	22.62	4.34	18.28	1.73	1.09	.05	1.16	1.02	.23	.12	.54	69.6	54.4	15.2
3127....	Sept. 17	do.	1.0864	22.46	4.45	18.01	1.64	1.07	.02	1.09	1.08	.19	.11	.56	70.0	57.6	12.4
3143....	Sept. 20	Fruit condition good, foliage bad condition.	1.0967	25.17	4.12	21.05	1.48	1.03	.00	.96	1.07	.18	.09	.56	69.2	56.8	12.4
3174....	Sept. 24	do.	1.0955	24.85	4.11	20.74	1.42	1.03	.02	.89	1.02	.19	.09	.57	67.2	54.4	12.8
3196....	Sept. 27	do.	1.0965	25.12	4.20	20.92	1.42	1.07	.00	.88	1.11	.18	.12	.59	70.8	58.8	12.0
3216....	Sept. 30	do.	1.0975	25.13	3.99	21.39	1.31	.87	.00	.82	.96	.11	.14	.56	64.8	50.8	14.0
3241....	Oct. 4	do.	1.0965	25.38	3.68	21.44	1.31	.87	.00	.83	.96	.10	.09	.52	64.0	51.2	12.8
3253....	Oct. 8	Wine ripe, foliage bad condition.	1.0995	25.91	4.74	21.17	1.43	1.15	.00	.86	1.31	.11	.17	.70	84.0	69.6	14.4
3282....	Oct. 15	do.	1.0991	25.80	4.79	21.01	1.43	1.00	.00	.81	1.25	.00	.20	.70	83.2	66.8	16.4
3296....	Oct. 18	Wine ripe, foliage gone.	1.0999	26.01	4.62	21.39	1.33	.97	.00	.73	1.20	.01	.20	.68	79.2	63.6	15.6
3306....	Oct. 22	Still good condition, foliage gone.	1.0986	25.67	4.30	21.37	1.32	.91	.00	.75	1.10	.03	.22	.63	76.0	58.4	17.6
3313....	Oct. 25	do.	1.1011	26.33	4.72	21.61	1.33	.95	.00	.79	1.09	.08	.06	.65	74.0	58.0	10.0
3325....	Oct. 29	Fruit fair, heavy frosts.	1.1031	26.85	4.25	22.60	1.31	.96	.00	.75	1.08	.10	.13	.62	74.4	57.2	17.2
Delaware.																	
3036....	Aug. 13	Bunches good, berries 50 per cent colored.	1.0677	17.56	3.26	14.30	1.42	.91	.20	.87	.65	.19	.01	.33	47.4	34.6	12.8
3041....	Aug. 16	Bunches good, berries more than 50 per cent colored.	1.0732	19.00	2.95	16.05	1.14	.77	.12	.69	.57	.19	.02	.31	43.4	30.5	12.9
3046....	Aug. 20	Bunches good, all colored	1.0799	20.75	2.54	18.21	.96	.64	.08	.60	.50	.15	.02	.28	36.8	26.8	10.0
3051....	Aug. 23	Fine fruit, ripens rapidly.	1.0836	22.25	2.62	19.63	.89	.65	.08	.53	.54	.14	.03	.22	38.0	28.8	9.2
3057....	Aug. 27	do.	1.0836	22.25	2.22	20.03	.80	.59	.04	.49	.50	.15	.02	.27	36.4	26.4	10.0
3063....	Aug. 30	do.	1.0904	23.51	2.40	21.11	.71	.59	.03	.40	.50	.16	.02	.29	37.2	26.4	10.8
3070....	Sept. 3	Berry moth serious.	1.0979	25.49	2.42	23.07	.67	.54	.04	.38	.41	.17	.01	.25	33.2	21.6	11.6
3078....	Sept. 6	Picked for wine, moth becoming more serious.	1.0995	25.91	2.46	23.45	.60	.50	.00	.32	.46	.13	.02	.27	36.8	24.4	12.4
3100....	Sept. 10	Holding about the same.	1.0986	25.67	2.27	23.40	.57	.50	.05	.30	.38	.14	.02	.28	30.0	20.4	9.6
3109....	Sept. 13	Moth injury checked.	1.1052	27.41	2.65	24.76	.67	.57	.01	.28	.50	.16	.02	.29	37.2	26.4	10.8
3129....	Sept. 17	Fruit wine ripe.	1.1040	27.09	2.63	24.46	.60	.51	.00	.31	.52	.10	.02	.28	38.4	27.6	10.8
3145....	Sept. 20	Condition holding.	1.1066	28.10	2.68	25.10	.58	.53	.00	.29	.54	.10	.02	.30	38.0	28.8	9.2
3176....	Sept. 24	Fruit deteriorating.	1.1127	29.39	3.00	26.39	.62	.58	.00	.28	.65	.05	.02	.37	44.8	34.8	10.0
3198....	Sept. 27	Fruit falling.	1.1137	29.65	2.99	26.66	.57	.54	.12	.24	.44	.07	.02	.24	28.0	23.2	4.8
3218....	Oct. 1	Fruit falling badly.	1.1161	30.28	3.02	27.26	.59	.64	.00	.25	.65	.12	.02	.38	46.0	34.8	11.2
Ives:																	
3035....	Aug. 13	Fine bunches, berries all colored.	1.0557	14.43	3.12	11.31	1.31	.94	.26	.71	.69	.13	.03	.33	45.6	36.7	8.9
3040....	Aug. 16	do.	1.0602	15.61	3.01	12.60	1.07	.85	.16	.57	.69	.13	.05	.33	45.8	36.9	8.9
3045....	Aug. 20	Fine bunches, ripening.	1.0644	16.70	2.88	13.82	.84	.74	.15	.39	.59	.12	.03	.30	39.6	31.6	8.0
3050....	Aug. 23	Fine bunches, becoming sweet.	1.0700	18.16	2.72	15.44	.84	.79	.17	.36	.64	.11	.05	.33	41.6	34.0	7.6
3056....	Aug. 27	do.	1.0684	17.15	2.53	15.22	.77	.71	.10	.36	.65	.10	.05	.31	40.8	34.4	6.4
3062....	Aug. 30	Condition holding.	1.0718	18.63	2.73	15.90	.64	.65	.07	.28	.59	.10	.05	.30	38.4	31.6	6.8
3069....	Sept. 3	Berry moth appearing.	1.0765	19.86	2.51	17.35	.65	.63	.03	.32	.59	.13	.05	.32	40.0	31.2	8.8
3072....	Sept. 6	Fairly good, condition holding.	1.0771	20.02	2.61	17.41	.62	.62	.02	.30	.60	.13	.06	.29	40.0	32.0	8.4
3079....	Sept. 10	do.	1.0744	19.31	3.03	16.28	.77	.69	.20	.32	.50	.10	.07	.34	43.2	26.4	6.8
3108....	Sept. 13	do.	1.0757	20.44	3.19	17.25	.60	.65	.04	.26	.60	.13	.07	.31	40.4	32.0	8.4

¹ Largely malic acid; formula for calculation given in the text.

TABLE 1.—*Analyses of grapes at different dates during maturity—Continued.*

1911 SAMPLES FROM SANDUSKY, OHIO (EOFF AND SHERWOOD, ANALYSTS)—Continued.

Variety and laboratory number of sample.	Date analyzed.	Condition of fruit.	Specific gravity.	Total solids.	Sugar-free solids.	Total sugar as invert.	Total acid as tartaric.	Total tartaric acid and tartarates.	Free tartaric acid.	Fixed acid other than tartaric.	Cream of tartar.	Tartaric acid to alkaline earths.	Tannin.	Crude ash.	Alkalinity of ash expressed in cubic centimeters of tenth-normal hydrochloric acid.		
															Total.	Water-soluble.	Water-insoluble.
Ives—Con.	Sept. 17	Moth doing injury.....	1.0807	20.96	3.47	17.49	0.68	0.73	0.01	0.31	0.78	0.10	0.11	0.38	48.0	41.2	6.8
	Sept. 20	Wine ripe, fair condition.....	1.0805	20.91	3.55	17.36	.70	.79	.01	.30	.82	.13	.08	.41	52.9	43.6	8.4
	Sept. 24	Condition holding.....	1.0803	20.86	3.63	17.33	.71	.78	.00	.32	.82	.13	.08	.41	52.4	43.6	8.8
	Sept. 27	do.....	1.0814	21.07	3.36	17.71	.73	.73	.00	.34	.84	.06	.08	.38	52.0	44.3	7.6
	Oct. 1	do.....	1.0793	20.60	3.63	17.07	.62	.71	.00	.26	.74	.12	.08	.38	48.0	39.2	8.8
Norton.	Oct. 4	do.....	1.0797	20.70	3.21	17.49	.62	.75	.00	.25	.78	.12	.07	.39	50.0	41.6	8.4
	Aug. 13	Good bunches, no color.....	1.0348	9.00	6.69	2.31	4.51	1.02	1.01	3.20	1.47	.23	.04	.50	40.1	124.8	15.3
	Aug. 16	Good bunches, slight color.....	1.0447	11.57	5.90	5.67	3.83	1.40	.34	2.97	.82	.41	.02	.43	71.1	43.5	27.6
	Aug. 20	Fine bunches, 75 per cent slight color.	1.0623	16.15	5.21	10.94	2.98	1.17	.16	2.31	.85	.33	.01	.47	67.2	45.2	22.0
	Aug. 23	Fine bunches, 90 per cent colored.....	1.0727	18.87	5.08	13.79	2.74	1.16	.27	2.03	.69	.34	.03	.38	59.2	36.8	22.4
3053	Aug. 27	do.....	1.0781	20.28	4.44	15.84	2.20	1.02	.00	1.68	.96	.26	.03	.47	68.8	50.8	18.0
	Aug. 30	Fine bunches, all colored.....	1.0807	20.96	5.00	15.96	2.11	1.10	.00	1.53	1.09	.23	.03	.53	77.2	58.0	19.2
	Sept. 3	Some moth, all colored.....	1.0967	25.17	5.28	19.89	1.95	1.80	.00	1.36	1.10	.20	.05	.54	78.4	58.4	20.0
	Sept. 6	Moth worse, beginning to ripen.....	1.0955	24.85	5.14	19.71	1.80	1.14	.00	1.16	1.22	.17	.06	.56	86.0	64.8	21.2
	Sept. 10	Moth same, ripening.....	1.0929	24.17	4.79	19.38	1.55	1.08	.15	.93	.87	.24	.07	.57	62.0	46.0	16.0
	Sept. 13	do.....	1.0986	25.67	4.82	20.85	1.61	1.11	.00	1.00	1.18	.17	.08	.56	62.0	62.8	19.2
	Sept. 17	do.....	1.1006	26.20	4.88	21.32	1.50	1.06	.00	.88	1.22	.08	.12	.57	83.2	64.8	18.4
	Sept. 20	Moth serious, picked for wine.....	1.1068	28.23	5.16	22.67	1.51	1.07	.00	.83	1.32	.02	.12	.61	90.8	70.0	20.8
	Sept. 24	Moth serious, not fully ripe.....	1.1084	28.25	5.22	23.03	1.41	1.15	.00	.70	1.40	.03	.12	.64	91.6	74.4	17.2
	Sept. 27	do.....	1.1056	27.51	4.84	22.67	1.34	1.11	.00	.70	1.35	.04	.11	.65	86.0	71.6	14.4

* Abnormal.

1911 SAMPLES FROM CHARLOTTEVILLE, VA. (HARTMANN, ANALYST).

Concord:	2880	Aug. 9	Good bunches, 90 per cent colored.	1.0515	13.34	3.10	10.24	1.52	0.88	0.07	1.04	0.88	0.11	0.03	0.40	54.0	46.8	7.2
	2885	Aug. 9	do.	1.0583	15.10	2.92	12.18	1.13	.75	.04	.74	.75	.11	.02	.39	47.2	40.0	6.8
	2890	Aug. 12	Good bunches, all colored.	1.0648	16.80	2.50	14.30	.98	.69	.00	.62	.78	.06	.03	.39	48.4	41.6	7.4
	2894	Aug. 16	do.	1.0691	17.94	2.30	15.64	.80	.68	.00	.41	.83	.11	.05	.40	51.8	44.4	4.4
	2898	Aug. 23	do.	1.0686	17.80	2.16	15.64	.74	.59	.00	.44	.68	.05	.02	.33	40.4	36.0	4.8
	2892	Aug. 26	Good bunches, nearly ripe.	1.0718	18.62	2.20	16.42	.62	.59	.00	.23	.74	.00	.02	.33	32.0	47.2	4.0
	2896	Aug. 30	Good bunches, wine ripe.	1.0747	19.40	2.04	17.36	.53	.56	.00	.24	.65	.04	.03	.32	38.8	34.8	6.0
	2899	Aug. 30	Good bunches, holding.	1.0698	18.10	2.42	15.68	.61	.59	.00	.31	.65	.08	.03	.37	40.4	34.4	3.6
	2913	Sept. 5	Deteriorating, fruit burst.	1.0736	19.10	2.50	16.60	.60	.68	.05	.23	.72	.05	.06	.39	42.0	38.4	
	Cynthiana:	2882	Aug. 5	Good bunches, 40 per cent slight color.	1.0493	12.76	5.16	7.60	3.21	1.20	.06	2.58	1.20	.19	.02	.56	76.0	63.6	12.4
2887		Aug. 9	do.	1.0585	15.16	4.50	10.56	2.88	1.13	.05	2.29	1.13	.18	.01	.50	72.0	60.0	12.0
Delaware:	2891	Aug. 12	Good bunches, 90 per cent colored.	1.0672	17.44	4.44	13.04	2.56	1.11	.00	2.00	1.16	.18	.02	.56	74.0	61.8	12.2
	2896	Aug. 16	Good bunches, all colored.	1.0785	19.66	4.06	15.60	2.03	.82	.00	1.51	1.02	.00	.02	.51	69.8	58.8	11.0
	2899	Aug. 23	do.	1.0785	20.38	3.48	16.90	1.61	.67	.00	1.26	.84	.15	.03	.42	46.0	35.0	11.0
	2903	Aug. 29	Good bunches, ripening.	1.0908	23.62	3.39	20.23	1.37	.81	.00	.93	.90	.09	.08	.49	58.0	48.0	10.0
	2907	Aug. 26	do.	1.0951	24.76	3.68	21.08	1.37	.74	.00	.86	.93	.00	.08	.52	68.4	57.6	10.8
	2910	Aug. 30	do.	1.0839	23.12	3.26	19.86	.97	.59	.00	.59	.74	.00	.06	.43	50.0	40.0	10.0
	2912	Sept. 2	Very fine bunches, ripening.	1.0975	25.38	4.02	21.36	.90	.57	.00	.55	.71	.00	.05	.42	46.8	36.6	7.2
	2915	Sept. 7	Very fine bunches, nearly ripe.	1.0951	24.78	3.69	21.08	.86	.65	.00	.39	.57	.00	.08	.54	63.2	56.0	7.2
	2920	Sept. 9	do.	1.0959	24.96	4.16	20.80	.78	.63	.00	.28	.79	.00	.10	.55	67.2	57.2	10.0
	2927	Sept. 15	Very fine bunches, wine ripe.	1.0951	24.93	3.27	21.66	.75	.60	.00	.26	.76	.00	.08	.53	65.0	53.0	12.0
Norton:	2879	Aug. 5	Good bunches, all show color.	1.0737	19.14	2.70	16.44	1.32	.80	.22	.81	.59	.12	.02	.31	39.2	31.2	8.0
	2884	Aug. 9	do.	1.0827	21.48	2.58	18.90	1.01	.71	.16	.58	.54	.11	.01	.30	36.4	28.8	7.6
	2889	Aug. 12	Good bunches, ripening.	1.0890	23.14	2.48	20.66	.93	.68	.08	.55	.62	.11	.02	.32	40.4	32.8	7.6
	2893	Aug. 16	do.	1.0949	24.70	2.44	22.26	.79	.61	.00	.45	.68	.07	.02	.35	44.8	36.0	8.8
	2897	Aug. 19	Good bunches, nearly ripe.	1.0986	25.68	2.45	23.23	.78	.57	.00	.36	.72	.00	.01	.33	55.6	45.2	10.4
	2901	Aug. 23	do.	1.1077	28.08	2.44	25.64	.69	.65	.00	.30	.82	.00	.01	.33	52.0	46.0	6.0
	2905	Aug. 26	Good bunches, wine ripe.	1.1084	28.24	2.44	25.80	.65	.68	.00	.30	.75	.08	.03	.34	46.0	40.0	6.0
	2878	Aug. 5	Good bunches, 40 per cent show color.	1.0529	13.70	5.34	8.36	3.34	1.17	.02	2.75	1.16	.22	.02	.59	76.4	61.6	14.8
	2883	Aug. 9	do.	1.0638	16.54	4.64	11.90	2.85	1.90	.08	2.26	1.02	.20	.02	.52	67.6	54.4	13.2
	2888	Aug. 12	Good bunches, 90 per cent show color.	1.0700	18.16	4.50	13.66	2.80	1.13	.00	2.20	1.23	.15	.02	.63	80.0	65.2	14.8
	2892	Aug. 16	Good bunches, all colored.	1.0787	20.44	3.87	16.57	2.13	.76	.00	1.60	.58	.00	.02	.51	71.0	54.8	16.2
	2896	Aug. 19	do.	1.0886	23.04	3.89	19.15	1.76	.62	.00	1.29	.78	.00	.05	.47	62.4	48.8	13.6
	2900	Aug. 23	Fine bunches, ripening.	1.0979	25.38	3.86	21.52	1.69	.80	.00	1.18	1.00	.00	.05	.56	68.6	53.8	14.8
	2904	Aug. 26	do.	1.0923	24.02	3.34	20.68	1.10	.80	.00	.63	1.00	.00	.06	.49	62.0	53.6	8.4
	2908	Aug. 30	do.	1.0957	24.90	3.50	21.40	1.05	.59	.00	.63	.74	.00	.06	.46	56.4	43.2	13.2
	2911	Sept. 2	do.	1.0947	24.64	2.98	21.66	1.02	.61	.00	.58	.76	.00	.07	.48	58.0	46.0	12.0
	2914	Sept. 7	Fine bunches, nearly ripe.	1.0996	25.94	3.76	22.18	.92	.62	.00	.41	.78	.00	.09	.52	68.0	54.8	13.6
	2919	Sept. 9	do.	1.0989	25.74	3.52	21.92	.92	.68	.00	.44	.85	.00	.01	.50	64.4	50.8	13.6
	2928	Sept. 19	Fine bunches, wine ripe.	1.0989	25.83	3.91	21.92	.80	.71	.00	.28	.88	.00	.10	.50	68.6	54.6	14.0

TABLE 1.—*Analyses of grapes at different dates during maturity—Continued.*

1912 SAMPLES FROM SANDUSKY, OHIO (INGLE, ANALYST).

Variety and laboratory number of sample.	Date analyzed.	Condition of fruit.	Specific gravity.	Total solids.	Sugar-free solids.	Total sugar as invert.	Total acid as tartaric.	Total tartaric acid and tartarates.	Free tartaric acid.	Fixed acid other than tartaric.	Cream of tartar.	Tartaric acid to alkaline earths.	Tannin.	Crude ash.	Alkalinity of ash expressed in cubic centimeters of tenth-normal hydrochloric acid.		
															Total.	Water soluble.	Water insoluble.
Concord:																	
3603....	Sept. 4	Good bunches, nearly all berries colored.	1.0490	12.69	4.09	8.60	1.91	0.93	0.47	1.21	0.50	0.06	.....	0.28	30.4	26.4	4.0
3607....	Sept. 9	do.....	1.0510	13.21	3.25	9.96	1.49	.83	.44	.85	.44	.04	.....	.25	26.4	23.2	3.2
3611....	Sept. 12	Good bunches, fine berries, all colored.	1.0555	14.33	3.06	11.32	1.31	.72	.32	.79	.41	.07	.....	.26	26.4	22.0	4.4
3615....	Sept. 17	Good bunches, fruit ripening.	1.0575	14.90	2.80	12.10	1.14	.72	.26	.65	.50	.05	.....	.27	30.4	26.8	3.6
3619....	Sept. 24	Good bunches, nearly ripe.	1.0655	17.01	2.86	14.15	1.07	.77	.22	.57	.60	.07	.....	.38	36.8	32.0	4.8
3624....	Oct. 1	Good bunches, apparently ripe, quality low.	1.0655	17.77	2.97	14.80	1.02	.77	.18	.55	.62	.10	.....	.41	38.2	32.8	6.4
3630....	Oct. 7	Good bunches, berries well developed, quality better.	1.0734	19.05	3.18	15.87	.99	.74	.13	.55	.68	.07	.....	.35	41.0	36.4	4.6
3654....	Oct. 16	Good bunches, sound, excellent condition, wine ripe.	1.0745	19.34	3.42	15.92	.95	.69	.04	.58	.77	.05	.....	.39	44.0	40.8	3.2
3674....	Oct. 23	Good bunches, sound, excellent condition, holding.	1.0744	19.31	3.44	15.87	.93	.67	.00	.56	.82	.01	.....	.41	49.0	43.4	5.6
3686....	Oct. 30	Deteriorating, fruit is dropping.	1.0748	19.42	3.40	16.02	.93	.74	.09	.51	.74	.07	.....	.40	43.6	39.2	4.4
3694....	Nov. 4	Leaves falling, fruit is dropping.	1.0743	19.29	3.71	15.58	.95	.88	.17	.42	.83	.05	.....	.44	47.8	44.2	3.6
3702....	Nov. 8	Frost has about ruined fruit.	1.0734	19.05	3.44	15.61	.90	.72	.05	.51	.76	.07	.....	.45	44.4	40.2	4.2
Catawba:																	
3605....	Sept. 4	Bunches fair, berries all green.	1.0329	8.51	4.90	3.60	3.68	1.20	.79	2.69	.39	.10	.....	.23	27.2	20.8	6.4
3609....	Sept. 9	Bunches fair, few berries show pink.	1.0419	10.84	4.16	6.68	3.02	1.08	.65	2.16	.41	.10	.....	.25	28.4	21.8	6.6
3613....	Sept. 12	Bunches uneven, 10 per cent berries show pink.	1.0515	13.34	3.99	9.35	2.48	.90	.45	1.80	.46	.08	.....	.27	30.0	24.4	5.6
3617....	Sept. 17	Bunches uneven, 25 per cent berries are pink.	1.0537	13.91	3.53	10.38	2.12	.90	.47	1.44	.45	.07	.....	.24	28.8	24.0	4.8
3621....	Sept. 24	Bunches uneven, 60 per cent berries are pink.	1.0569	14.74	3.41	11.33	1.74	.73	.20	1.28	.53	.11	.....	.31	35.2	28.0	7.2
3626....	Oct. 1	Bunches uneven, 85 per cent berries are pink.	1.0614	15.92	3.17	12.75	1.63	.80	.31	1.07	.54	.06	.....	.31	32.8	28.8	4.0
3632....	Oct. 7	Bunches uneven, condition same.	1.0663	17.20	3.41	13.79	1.53	.80	.23	1.02	.61	.08	.....	.33	37.6	32.6	5.0
3656....	Oct. 16	Bunches uneven, all colored.	1.0725	18.82	3.47	15.35	1.34	.78	.23	.83	.61	.06	.....	.33	36.4	32.4	4.0

Particular attention is called to the data on sugar and acids. The Catawba crop studied in 1911 was harvested October 1 to 4, and though certain plants were held and sampling was continued 25 days longer, the results show only a gain of 1.22 grams of sugar and the loss of 0.24 gram of acid in 100 cc of juice. The apparent increase of sugar was doubtless due to evaporation of water from the berries and the loss of acid is possibly accounted for in the loss of malic acid. This would probably have disappeared in wine fermentation,¹ giving practically the same or a lower result than that recorded for the last sample. It is certain that nothing would have been gained for commercial purposes by holding this particular crop on the vine after the date it was harvested.

It is not to be understood that the dates of full-crop ripeness given in the tables apply to all the vineyards of the Sandusky district. On the contrary, these dates apply only to the crops sampled. The season for Catawba in the Sandusky district lasts fully 3 weeks and the ripening of other varieties extends over a considerable period, varying with location.

Clinton was sampled for 21 days after the crop was picked, but shows only an increase of 1.43 grams of sugar and a loss of 0.18 gram of acid. This variety lost most of its foliage before the fruit was picked on October 7 and 8 and the later samples were picked from vines practically bare of leaves. This undoubtedly had an influence on the high acid shown. In fact, this crop of Clinton shows the maximum acid at ripening of all the crops of this variety examined at Sandusky during the season of 1911. The fact that this variety showed such high content of both malic acid and cream of tartar at ripening should be noted in this connection, because the presence of those elements greatly assists in the reduction of the acid of the finished products from this variety. This occurs by precipitation of the crude tartar both in grape juices and wines and by destruction of malic acid with the formation of lactic acid through bacterial fermentation² in case of wines.

The Delaware samples at Sandusky show the most notable increase of sugar after the date the crop was marked wine-ripe. However important it might appear to be to secure this increase of nearly 3 grams of sugar in 100 cc of juice, it is not practicable to hold this crop so late because of the injury to the fruit from birds, insects, and various other causes. The acid reduction was inappreciable, but as a matter of fact this variety has scarcely enough acid when it is fully ripe for the best results in dry-wine making. Note the unusually wide total acid-sugar ratio in Table 2.

Ives, though held on the vine 14 days after marked fully ripe, showed very slight changes in sugar and acid.

¹ Kulisch, Weinverbesserung, 3d ed., 1909, p. 19.

² Ibid.

The Norton samples were unfortunately destroyed by the berry moth before fully ripe, but the total sugar shown in this variety at Sandusky is remarkable, considering that it is distinctly a Southern grape. Possibly with extra effort it might be matured in the Sandusky district so as to show a lower acid content than it usually does.

The Concord grape samples at Charlottesville showed but small increase of sugar after they were fully colored. The season was very hot and dry and the fruit ripened quickly, then deteriorated rapidly, as shown by the analyses. This is the only variety sampled at Charlottesville after full maturity. The fruit burst and was badly attacked by birds and insects, hence the later samples were not normal.

Cynthiana was 30 days in reaching full maturity after the berries were colored. The increase of sugar during this long period was not really marked. The results show only about 40 per cent more sugar in the last than in the first sample; but the loss in acid in 100 cc of juice was 63 per cent. This gave a rich juice with a very moderate acid content—only 0.75 gram in 100 cc.

Delaware was sampled at Charlottesville for 21 days after the berries were colored until full ripeness. The increase of sugar was 57 per cent and the drop in acid slight. The final sugar content is too high for the acid strength, as is also noted for the Sandusky samples. This fruit can not well be held at Charlottesville for study after full maturity. It would, however, most likely show final sugar equal to the Sandusky samples. (Note that the acid-sugar ratio for Delaware at wine-ripeness is practically the same for both districts.)

Norton was sampled for 34 days at Charlottesville, after it was fully colored but before it was fully ripe, with an increase of only 5.35 grams of sugar in 100 cc of juice; but the decrease in acidity of 1.33 grams is the greatest noted for any variety from the period of full coloring until ripe. The final acid of 0.80 gram in 100 cc shown by this crop is remarkably favorable for this variety.

It is a noteworthy point that free tartaric acid practically disappeared from the grapes having dark-colored juice, both at Sandusky and at Charlottesville, some time previous to maturity. The very large amount of fixed acids other than tartaric (which are treated in this discussion as malic acid), shown in the green Catawba, Clinton, Cynthiana, and Norton, is interesting. None of the other varieties nearly equal these four in this regard. The data show that the loss of acid during the maturity of the fruit is very largely due to the changing of the malic acid, but there is in every instance a greater loss of total acid than of malic. This is in accordance with what should normally occur through the combination of free tartaric with potassium and other bases forming cream of tartar and

alkaline-earth tartrates. So long as free tartaric acid is present the loss of malic acid is accounted for by the vital processes of the plant, but as soon as there is no longer free tartaric acid present, malic acid will combine with potassium and other bases which may continue to enter the fruit by influx of sap. It would appear that though the fruit was held on the vines at Sandusky until long overripe, the sugar apparently increased to the last and the malic acid decreased.

The total acidity of the first sample of Catawba is nearly twice the sugar content. Norton also shows the same relation, but all the other varieties show a much higher ratio of sugar to acid in the first samples. These two varieties develop their sugar content rapidly during the later period of growth and decline in acid content with marked rapidity. Note in this connection the ratio of loss of acid to increase of sugar in Table 2. The acid content of the Catawba sample when harvested was only 22 per cent of the acid shown in the first sample, and the last frosted sample of Catawba showed only about one-sixth of the acid contained in the first sample. Though the Norton crop at Sandusky did not fully ripen, the acid of the last sample was not quite 30 per cent of the first sample. The sugar of the last sample of these two varieties at Sandusky was approximately ten times that of the first sample. Clinton and Cynthiana do not show anything like such extremes, though varieties of about the same season and composition when ripe. Delaware, Ives, and Concord do not show these striking contrasts.

The results for cream of tartar are somewhat abnormal and should be checked by further complete analyses of the fresh fruit. It would appear that cream of tartar should increase in the fruit of the grape until fully ripe, or, more correctly, until all free tartaric acid disappears, but the evidence on this subject, to which there was access, is not conclusive. Certainly the results of the analyses of fresh juice thus far made do not fully support this presumption. Only the samples of Norton taken at Sandusky show a notable increase of cream of tartar at maturity. Ives and Clinton show also a slight increase. Delaware at Charlottesville shows a slight increase, but all other varieties show a decline of this substance. These results raise the question as to whether the cream of tartar can be wholly recovered by the method of extracting the juice followed in this laboratory. It is undoubtedly true that this substance is deposited as crystals when the juice is fully saturated, and especially will this be more pronounced as the acid content declines and the sugar content increases. The temperature of the sample might affect the results to a slight degree because of the varying solubility of cream of tartar at different temperatures.

Some interesting points are brought out by comparing the sugar and acid content from the date when all the berries were colored until fully ripe. The note "Berries, colored" is necessarily somewhat arbitrary, because the coloring of these varieties is not at all alike; but we have used it in the general sense understood by the grape growers. These comparisons are presented in Table 2:

TABLE 2.—Increase of sugar and decrease of acid for certain periods, 1911.

[Results in grams per 100 cc.]

SANDUSKY, OHIO.

Variety and date.	Condition of berries.	Days elapsed.	Total sugar.	Gain of sugar.	Total acid.	Loss of acid.	Ratio loss of acid to gain of sugar.	Acid-sugar ratio in ripe fruit.
Catawba:								
Aug. 27.....	Berries, colored.....		11.58	} 7.87	{ 2.21 .95	} 1.26	1: 6.2	1:20.5
Oct. 4.....	Wine-ripe.....	38	19.45					
Clinton:								
Aug. 23.....	Berries, colored.....		15.55	} 5.62	{ 2.28 1.49	} .79	1: 7.1	1:14.2
Oct. 8.....	Wine-ripe.....	46	21.17					
Delaware:								
Aug. 20.....	Berries, colored.....		18.21	} 6.25	{ .96 .60	} .36	1:17.4	1:40.8
Sept. 17.....	Wine-ripe.....	28	24.46					
Ives:								
Aug. 13.....	Berries, colored.....		11.31	} 6.05	{ 1.31 .70	} .61	1: 9.9	1:24.8
Sept. 20.....	Wine-ripe.....	38	17.36					
Norton:								
Aug. 30.....	Berries, colored.....		15.96	} 6.71	{ 2.11 1.34	} .77	1: 8.7	1:16.9
Sept. 27.....	Last sample ¹	28	22.67					

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Concord:								
Aug. 12.....	Berries, colored.....		14.30	} 3.06	{ 0.98 .53	} 0.45	1: 6.8	1:32.8
Aug. 26.....	Wine-ripe.....	14	17.36					
Cynthiana:								
Aug. 16.....	Berries, colored.....		15.60	} 6.06	{ 2.03 .75	} 1.28	1: 4.7	1:28.8
Sept. 15.....	Wine-ripe.....	30	21.66					
Delaware:								
Aug. 5.....	Berries, colored.....		16.44	} 9.36	{ 1.32 .65	} .67	1:13.9	1:39.7
Aug. 26.....	Wine-ripe.....	21	25.80					
Norton:								
Aug. 16.....	Berries, colored.....		16.57	} 5.35	{ 2.13 .80	} 1.33	1: 4.02	1:27.4
Sept. 19.....	Wine-ripe.....	34	21.92					

¹ Fruit was not fully ripe.

The summary of the data given in Table 2, on changes in sugar and acid content of these varieties from the time the berries were colored until wine-ripe, show striking differences in the ratios, loss of acid to gain of sugar, and total acid to total sugar, at full ripeness. The greatest loss of acid to gain of sugar, hence the lowest ratio, is shown by Cynthiana and Norton at Charlottesville, and Catawba at Sandusky. The full data given in Table 1 show in detail the development of these varieties and that when ripe they gave an excellent juice for wine making. The ratio for these three varieties as to total acid and sugar when fully ripe show that the Catawba at Sandusky was not so well balanced in acid and sugar content as the Cynthiana

and Norton at Charlottesville. The analyses of this Catawba crop, which was inferior to some others of the Sandusky district, show its high value for wine manufacture.

The extremely high ratio of gain in sugar to loss in acid shown by Delaware and the very wide ratio of total acid to sugar content in this variety bears out the previous statement that this grape is low in acid for commercial purposes. This grape would make a wine with an acid-alcohol ratio when finished of about 1 to 26, whereas 1 to 20 is about the right ratio for a potable wine of this class.

CROP OF 1912.

The work on development of acid and sugar content in grapes was confined during 1912 to two varieties, Concord and Catawba, at Sandusky, and also to two varieties, Delaware and Concord, at Charlottesville. The full data on the juice samples are given in Table 1. A much more complete study of the composition of the whole fruit was undertaken than heretofore, with results as given in Table 6. This later work consisted of fairly complete organic and ash analyses of the whole fruit, whereas the work done heretofore was confined to the expressed juice.

All of the fruit used in 1912 was taken from vines reserved for this work and the sampling was done in every instance by the same persons as in 1911.

The work at Sandusky was begun several weeks later than in 1911, but the first samples were taken before the fruit was fully colored. The crop was late and Catawba developed unevenly and was not in prime condition at any time. In fact the Catawba crop used for this work failed to mature properly and did not fully ripen; 1912 was a poor crop year for all the late grapes in northern Ohio. At Charlottesville the fruit ripened promptly and was in excellent condition.

A comparison of the sugar and the acid elements in the composition of Catawba for the two years, 1911 and 1912, are presented in Table 3. The results for 1912 are taken from the date when the fruit was noted as showing pink color instead of fully colored, as in 1911. The coloring of this fruit in different years varies greatly, but the sugar and acid content indicates comparatively the same stage of ripeness when the first samples used in the comparison were taken. As the dates of sampling for the two years are not the same, two dates are given for each line in the date column at the left of the table. The first date in each case is the date of sampling for 1911 and the second for 1912. The comparison does not include all the analyses for 1911, but does give those which mark the several stages of maturity to the date when the crop was fully ripe, and the results are given for 1912 until the fruit was destroyed by frost.

TABLE 3.—*Comparison of sugar and acid elements in Catawba fruit, 1911-12.*

Dates when sampled.		Sugar.		Total acid.		Tartaric acid.				Fixed acids other than tartaric.		Cream of tartar.	
						Total.		Free.					
1911	1912	1911	1912	1911	1912	1911	1912	1911	1912	1911	1912	1911	1912
Aug. 20	Sept. 9	7.22	6.68	3.35	3.02	0.98	1.08	0.22	0.65	2.75	2.16	0.75	0.41
Aug. 23	Sept. 12	9.46	9.35	2.96	2.48	1.01	.90	.22	.45	2.35	1.80	.80	.46
Aug. 27	Sept. 17	11.58	10.38	2.21	2.12	.79	.90	.15	.47	1.74	1.44	.65	.45
Aug. 30	Sept. 24	12.32	11.33	1.98	1.74	.74	.73	.08	.20	1.57	1.28	.67	.53
Sept. 3	Oct. 1	15.24	12.75	1.50	1.63	.59	.80	.05	.31	1.18	1.07	.53	.54
Sept. 6	Oct. 7	16.08	13.79	1.28	1.53	.53	.80	.03	.23	1.00	1.02	.48	.61
Sept. 10	Oct. 16	16.28	15.35	1.19	1.34	.57	.78	.19	.23	.81	.83	.37	.61
Sept. 13	Oct. 23	17.28	15.01	1.12	1.28	.60	.64	.08	.08	.78	.91	.50	.59
Sept. 20	Oct. 29	19.44	16.49	.99	1.22	.48	.75	.00	.23	.73	.73	.53	.57
Sept. 27	Nov. 4	19.94	16.77	.89	1.28	.50	.84	.00	.23	.63	.74	.53	.71
Oct. 4	Nov. 8	19.45	16.39	.95	1.09	.58	.79	.04	.29	.64	.55	.56	.52

The crop of 1911 was of excellent quality for wine making purposes, while that of 1912 was distinctly poor, yet the sugar content varies only about 3 grams at the final examinations given in Table 3. This result agrees with our study of general crop samples in good and poor crop years, as shown in Bureau of Chemistry Bulletin 145.

The acid elements are more difficult and complex as to comparison. In total acid the crop of 1911 exceeds that of 1912 for the first several samples compared, but gradually declines until it falls below the latter. The final difference, however, is not marked. The fact that free tartaric acid in appreciable quantity continues present in the 1912 crop is important from a manufacturing point of view, because this acid can not be eliminated from the products except by the artificial introduction of a base such as potassium or calcium.

The fixed acids other than tartaric (malic) are interesting in that for the good crop year (1911) the values obtained in the early stages were much greater than in 1912, while at the end of the season the two crops were about alike. The total tartaric acid of the poor crop (1912) sensibly exceeded that of the 1911 crop and the free tartaric acid markedly exceeded that found in 1911 in the early samples and at the time of harvesting still maintained this excess.

The remarks on the analytical results for cream of tartar given under "Crop of 1911" apply to the consideration of the results obtained for the juice samples analyzed in 1912. The juice samples of 1912 also show exceptions which, though not so marked, are noticeable. The varieties sampled in 1912 show, with one exception, an increase of cream of tartar as the fruit matured, whereas in 1911 the samples are not uniform in this regard. This lack of logical results in regard to the content of cream of tartar, and also other considerations, led us to examine whole fruit samples in 1912. The fruit sample was treated in such manner that the entire content of

cream of tartar was recovered, so far as this could be accomplished in water solution. These data are presented in a subsequent section of this paper.

TABLE 4.—*Increase of sugar and decrease of acid for certain periods, 1912.*

[Results in grams per 100 cc.]

SANDUSKY, OHIO.

Date.	Condition of berries.	Days elapsed.	Total sugar.	Gain of sugar.	Total acid.	Loss of acid.	Ratio loss of acid to gain of sugar.	Acid-sugar ratio in ripe fruit.
Concord:								
Sept. 4.....	Nearly all colored.....		8.60	} 7.32	{ 1.91 .95	} 0.96	1: 7.6	1: 16.7
Oct. 16.....	Fully ripe.....	42	15.92					
Catawba:								
Sept. 17.....	Partly colored.....		10.38	} 6.39	{ 2.12 1.28	} .84	1: 7.6	1: 13
Nov. 4.....	Not fully ripe.....	48	16.77					

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Delaware:								
Aug. 2.....	60 per cent colored.....		13.08	} 12.70	{ 1.92 .69	} 1.23	1: 10	1: 37.3
Aug. 30.....	Fully ripe.....	28	25.78					
Concord:								
Aug. 2.....	60 per cent colored.....		5.16	} 10.05	{ 2.46 .80	} 1.66	1: 6.1	1: 19
Aug. 30.....	Fully ripe.....	28	15.21					

COMPOSITION OF THE WHOLE FRUIT.

A portion of each fruit sample used for the juice analysis in 1912 was taken to make a fairly complete analysis of the whole fruit used for the acid-sugar investigation. The method followed in taking and handling the samples for this work has been given with sufficient detail under "Sources and preparation of samples."

The apparent irregularity in the increased content of cream of tartar as the fruit matured and the fact that crystals of this salt are deposited in the fruit during ripening first suggested the complete exhaustion of the organic salts from the berries. Then the further considerations as to whether the total weight of acid present in the fruit really decreased during ripening or was simply reduced in percentage by reason of the influx of sap and by the formation of sugar in the fruit was a point requiring investigation. This latter question was suggested by some critical discussion of the results obtained in 1911, during which it was pointed out by colleagues in the Bureau of Chemistry that it had not been definitely shown that acid was eliminated during ripening, though this appeared from the results to be the case. This discussion led the authors to include in the work for 1912 determination of the volume in cubic centimeters, the specific gravity, and the exact weight in grams, of 100 berries from the composite sample taken for the juice analysis. There was also concluded a fairly complete ash analysis of a portion

of this whole fruit sample. The physical examinations noted were made in triplicate and the average results used in the table. From these results, in connection with the analyses of the completely extracted fruit samples, some comparisons of definite value in regard to the actual weight content of acid in 100 berries at different periods of maturity may be drawn.

RELATIVE ACTUAL WEIGHT OF TOTAL ACID IN GREEN AND RIPE FRUIT.

The volume of the 100 berries was determined by displacement of water, and the specific gravity was determined by weighing first in air and then in water and calculating the gravity.

It was found necessary to rinse the berries with a weak solution of alcohol (10 to 15 per cent) in order to obviate the formation of air bubbles on the surface, which otherwise markedly interfered with both the volume measurement and the weighing for specific gravity.

The volume and weight of the Concord berries did not show marked changes in size of the fruit throughout the period of the examinations of the samples, but for Catawba there was a decided increase of about 39 per cent in volume and about 44 per cent in weight. It appears that this late-maturing variety for that season shows considerable change in size and weight of berries during the period from coloring to maturity.

On calculating the actual weight of acid in grams present for each sample of 100 berries examined there is shown in a positive manner, in Table 5, a fairly constant diminution in total weight of this ingredient. The percentage of acid in the water-exhausted sample is used for this calculation. There are some apparently abnormal results; that is, during some periods the actual weight of acid increased slightly, yet this is invariably reversed for the subsequent analysis and the comparison of the first samples and the last taken show a positive loss in total weight of acid present in 100 berries for all the crops analyzed. The data appear to establish the fact that there is a very decided loss in total weight of acid as the fruit ripens. The weight loss is in case of Concord, both at Charlottesville and Sandusky, approximately one-half the total acid found in the first sample. For Catawba the proportion falls slightly under one-half the original acid.

These results are such as should be expected from the analysis of juice samples, wherein it is shown in Table 1 that the fixed acids other than tartaric disappear to a marked extent as the fruit ripens. The results presented in Table 7 also support this contention. While it is also true that the total tartaric acid is shown by Table 1 to decline, this is not so marked and does not nearly account for the actual loss in weight of acid shown in Table 5.

TABLE 5.—*Measurements and weights of samples of 100 berries compared with percentage total acid and actual acid by weight in samples of 100 berries, 1912.*

SANDUSKY, OHIO.

Variety and laboratory number of sample.	Date analyzed.	Specific gravity of fruit weighed in water.	Volume of 100 berries.	Weight of 100 berries.	Total acid in water-extracted sample.	Actual weight of acid in 100 berries.	Differences in weight for each period. ¹
Catawba:			<i>Cc.</i>	<i>Grams.</i>	<i>Per cent.</i>	<i>Grams.</i>	<i>Gram.</i>
3606.....	Sept. 4	1.048	157.9	165.5	3.15	5.21	.....
3610.....	Sept. 9	1.056	172.7	182.5	2.60	4.75	—0.46
3614.....	Sept. 12	1.061	165.7	175.8	2.17	3.81	— .94
3618.....	Sept. 17	1.063	187.0	198.9	2.01	4.00	+ .19
3622.....	Sept. 24	1.066	185.1	197.4	1.64	3.24	— .76
3627.....	Oct. 1	1.072	205.2	220.0	1.55	3.41	+ .17
3633.....	Oct. 7	1.077	207.0	222.8	1.47	3.28	— .13
3657.....	Oct. 16	1.082	215.0	232.8	1.30	3.03	— .25
3677.....	Oct. 23	1.085	197.4	213.8	1.27	2.72	— .31
3689.....	Oct. 30	1.086	219.7	238.5	1.21	2.89	+ .17
3697.....	Nov. 4	Lost.	218.8	236.2	1.17	2.76	— .13
Concord:							
3604.....	Sept. 4	1.057	229.1	242.2	1.83	4.43	.....
3608.....	Sept. 9	1.059	239.1	253.3	1.42	3.60	— .83
3512.....	Sept. 12	1.061	228.0	242.0	1.31	3.17	— .43
3616.....	Sept. 17	1.062	241.8	256.9	1.16	2.98	— .19
3620.....	Sept. 24	1.073	242.1	259.7	1.06	2.75	— .23
3625.....	Oct. 1	1.073	242.0	260.1	1.01	2.63	— .12
3631.....	Oct. 7	1.080	236.3	255.2	1.05	2.68	+ .05
3655.....	Oct. 16	1.082	241.0	260.8	.96	2.50	— .12
3675.....	Oct. 23	1.080	235.9	255.0	.95	2.42	— .08
3687.....	Oct. 30	1.083	221.3	239.5	.91	2.18	— .24
3695.....	Nov. 4	Lost.	228.3	245.2	.93	2.28	+ .10

CHARLOTTESVILLE, VA.

Concord:							
3582.....	Aug. 2	1.053	227.6	240.3	2.20	5.29	.....
3589.....	Aug. 7	1.059	245.6	259.7	1.68	4.36	—0.93
3592.....	Aug. 13	1.062	231.4	245.8	1.28	3.15	—1.21
3595.....	Aug. 21	1.074	258.2	277.2	.98	2.72	— .43
3600.....	Aug. 30	1.076	247.3	266.0	.85	2.26	— .46
Delaware:							
3583.....	Aug. 2	1.073	94.4	101.4	(2)	(2)	(2)
3591.....	Aug. 7	1.087	117.6	127.9	(2)	(2)	(2)
3593.....	Aug. 13	1.094	121.7	133.1	(2)	(2)	(2)
3596.....	Aug. 21	1.106	125.2	138.6	(2)	(2)	(2)
3601.....	Aug. 30	1.114	116.2	129.4	(2)	(2)	(2)

¹ Total loss in weight of acid in 100 berries: Catawba, 2.45 grams; Concord (Sandusky), 2.15 grams; Concord (Charlottesville), 3.03 grams.

² Data not complete.

ANALYTICAL RESULTS ON THE WHOLE FRUIT SAMPLES.

The data on the examinations made of whole-fruit samples are given in Table 6. These figures are necessarily percentages of the weighed fruit sample. Therefore, for the purpose of comparison, the results for sugar and acid of the juice samples given in Table 1 are calculated to percentages and these data for both juice and whole fruit samples are brought together in Table 7.

TABLE 6.—*Analyses of whole-fruit samples, 1912.*¹
SANDUSKY, OHIO (BOFF, ANALYST).

{Results in per cent of weighed sample.}

Variety and laboratory number of sample.	Treatment.	Date analyzed.	Sugar as invert.	Total acid as tartaric.	Total tartaric acid.	Free tartaric acid.	Fixed acid other than tartaric. ²	Cream of tartar.	Tartaric acid to alkaline earths.	Crude ash.	Alkalinity of ash expressed in cubic centimeters of tenth-normal hydrochloric acid in 100 grams of fruit.			Phosphoric acid (P ₂ O ₅).			Chlorin.	Potassium oxid.	Sodium oxid.	Calcium oxid.	Magnesium oxid.	
											Total.	Water-soluble.	Water-insoluble.	Total.	Soluble.	Insoluble.						
Catawba:																						
3606.....	Water extraction of whole fruit.....	Sept. 4	3.29	3.15	0.90	0.40	2.50	0.46	0.15	0.324	34.0	24.5	9.5	0.015	0.002	0.015						
3606.....	Whole fruit ashed.....	do.								.383	35.8	25.0	10.8	.0428	Trace.	.016						
3610.....	Water extraction of whole fruit.....	Sept. 9	5.71	2.60	.86	.29	2.02	.52	.16	.360	38.0	27.5	10.5	.016	.003	.061						
3610.....	Whole fruit ashed.....	do.								.414	35.8	25.8	10.0	.064	Trace.	.012						
3614.....	Water extraction of whole fruit.....	Sept. 12	8.07	2.17	.99	.34	1.51	.63	.15	.369	43.5	33.5	10.0	.012	Trace.	.012						
3614.....	Whole fruit ashed.....	do.								.424	38.6	29.2	9.4	.0578	.001	.0568						
3618.....	Water extraction of whole fruit.....	Sept. 17	8.51	2.01	.77	.14	1.55	.59	.15	.392	41.5	32.5	9.0	.012	Trace.	.012						
3618.....	Whole fruit ashed.....	do.								.425	40.6	33.0	7.6	.0478	.0028	.0450						
3622.....	Water extraction of whole fruit.....	Sept. 24	9.64	1.64	.72	.06	1.24	.66	.15	.375	44.5	34.8	9.8	.010	Trace.	.010						
3622.....	Whole fruit ashed.....	do.								.392	40.0	32.0	8.0	.0508	.0028	.0480						
3627.....	Water extraction of whole fruit.....	Oct. 1	11.02	1.55	.71	.06	1.18	.63	.15	.369	43.5	33.3	10.0	.028	.007	.021						
3627.....	Whole fruit ashed.....	do.								.428	37.0	28.4	8.6	.0624	.1156	.0568						
3633.....	Water extraction of whole fruit.....	Oct. 7	11.72	1.47	.78	.06	1.05	.75	.13	.432	48.3	40.0	8.3									
3633.....	Whole fruit ashed.....	do.								.440	40.0	31.0	9.0									
3657.....	Water extraction of whole fruit.....	Oct. 16	3.57	1.30	.85	.16	.79	.72	.12	.442	46.3	38.5	7.8									
3657.....	Whole fruit ashed.....	do.								.442	40.2	29.4	10.8									
3677.....	Water extraction of whole fruit.....	Oct. 23	13.26	1.27	.75	.07	.86	.72	.11	.413	45.3	38.3	7.0									
3677.....	Whole fruit ashed.....	do.								.474	40.8	32.4	8.4									
3689.....	Water extraction of whole fruit.....	Oct. 30	13.81	1.21	.79	.06	.79	.77	.13	.456	49.0	40.8	8.3									
3689.....	Whole fruit ashed.....	do.								.482	41.4	33.0	8.4									
3697.....	Water extraction of whole fruit.....	Nov. 4	11.61	1.17	.84	.17	.67	.80	.06	.449	46.3	42.5	3.8									
3697.....	Whole fruit ashed.....	do.								.521	42.1	33.4	9.0									
Concord:																						
3604.....	Water extraction of whole fruit.....	Sept. 4	7.23	1.83	.82	.16	1.34	.73	.09	.420	44.0	38.5	5.5	.021	.003	.019						
3604.....	Whole fruit ashed.....	do.								.378	44.0	37.4	6.6	.0506	.0104	.0402						
3608.....	Water extraction of whole fruit.....	Sept. 9	8.52	1.42	.68	.10	1.05	.66	.14	.415	43.5	35.0	8.5	.025	Trace.	.025						
3608.....	Whole fruit ashed.....	do.								.415	41.2	34.8	6.4	.0516	.0056	.0460						
3612.....	Water extraction of whole fruit.....	Sept. 12	9.82	1.31	.86	.14	.81	.74	.13	.403	48.0	39.5	8.5	.009	Trace.	.009						
3612.....	Whole fruit ashed.....	do.								.431	46.6	39.0	7.6	.0458	.001	.0448						

² Formula for calculation given in the text.¹ In each case of water extraction the results are the average of two determinations.

TABLE 6.—*Analyses of whole-fruit samples, 1912—Continued.*
SANDUSKY, OHIO (EOFF, ANALYST)—Continued.

Concord— Variety and laboratory	Treatment.	Date analyzed.	Sugar as invert.	Total acid as tartaric.	Total tartaric acid.	Free tartaric acid.	Fixed acid other than tartaric.	Cream of tartar.	Tartaric acid to alkaline earths.	Crude ash.	Alkalinity of ash expressed in cubic centimeters of tenth-normal hydrochloric acid in 100 grams of fruit.			Phosphoric acid (P ₂ O ₅).			Chlorin.	Potassium oxid.	Sodium oxid.	Calcium oxid.	Magnesium oxid.
											Total.	Water-soluble.	Water-insoluble.	Total.	Soluble.	Insoluble.					
3616.....	Water extraction of whole fruit.	Sept. 17	10.49	1.16	0.71	0.03	0.80	0.71	0.12	0.393	45.3	37.8	7.5	0.017	Trace.	0.017	0.0021	0.2054	0.0030	0.0327	0.0228
3616.....	Whole fruit ash.	do.								.429	43.4	37.8	5.6	.043	0.0056	.0374					
3620.....	Water extraction of whole fruit.	Sept. 24	12.58	1.06	.68	.00	.69	.78	.07	.416	50.5	41.5	9.0	.013	Trace.	.013	.0007	.2173	.0036	.0295	.0214
3620.....	Whole fruit ash.	do.								.445	43.8	38.2	7.6	.0440	.0076	.0364					
3625.....	Water extraction of whole fruit.	Oct. 1	12.43	1.01	.76	.03	.62	.75	.14	.415	49.3	39.8	9.5	.028	.007	.021					
3625.....	Whole fruit ash.	do.								.446	43.6	37.0	6.6	.0510	.0086	.0424	.0014			.0308	.0217
3631.....	Water extraction of whole fruit.	Oct. 7	14.03	1.05	.74	.00	.62	.91	.02	.487	58.2	49.3	9.0								
3631.....	Whole fruit ash.	do.								.468	46.6	39.8	6.8								
3635.....	Water extraction of whole fruit.	Oct. 16		.96	.77	.00	.56	.91	.05	.477	54.3	48.3	6.0								
3635.....	Whole fruit ash.	do.								.478	53.0	46.8	6.3								
3675.....	Water extraction of whole fruit.	Oct. 23	13.05	.95	.75	.00	.55	.88	.05	.532	50.4	43.6	6.8								
3687.....	Whole fruit ash.	do.								.475	56.3	49.0	7.3								
3687.....	Water extraction of whole fruit.	Oct. 30	13.90	.91	.79	.00	.48	.92	.06	.527	49.0	40.6	8.4								
3695.....	Whole fruit ash.	do.								.493	58.3	52.0	6.3								
3695.....	Water extraction of whole fruit.	Nov. 4	10.65	.83	.91	.03	.47	.98	.10	.592	51.6	43.4	8.2								
3695.....	Whole fruit ash.	do.																			

CHARLOTTESVILLE, VA. (HARTMANN AND EOFF, ANALYSTS).

Concord:	Treatment.	Date analyzed.	Sugar as invert.	Total acid as tartaric.	Total tartaric acid.	Free tartaric acid.	Fixed acid other than tartaric.	Cream of tartar.	Tartaric acid to alkaline earths.	Crude ash.	Alkalinity of ash expressed in cubic centimeters of tenth-normal hydrochloric acid in 100 grams of fruit.			Phosphoric acid (P ₂ O ₅).			Chlorin.	Potassium oxid.	Sodium oxid.	Calcium oxid.	Magnesium oxid.
											Total.	Water-soluble.	Water-insoluble.	Total.	Soluble.	Insoluble.					
3588.....	Water extraction of whole fruit.	Aug. 2	5.56	2.20	1.22	0.52	1.33	0.73	0.12	0.349	46.5	39.0	7.5	0.029	0.010	0.019	0.0014	0.2705	0.0047	0.0261	0.0451
3588.....	Whole fruit ash.	do.								.513	49.8	38.0	11.8	.0465	.0070	.0395					
3590.....	Water extraction of whole fruit.	Aug. 7	7.83	1.68	1.04	.28	1.03	.79	.13	.391	50.3	41.8	8.5	.028	.011	.015	.0057	.2600	.0024	.0231	.0400
3590.....	Whole fruit ash.	do.								.522	57.6	46.4	11.2	.0498	.0042	.0456					
3594.....	Water extraction of whole fruit.	Aug. 13	9.75	1.28	.87	.06	.81	.85	.14	.448	54.3	44.9	9.4	.019	.009	.010	.0048	.2463	.0043	.014	.020
3594.....	Whole fruit ash.	do.								.514	45.4	37.1	8.3	.0257	.0035	.0222					
3597.....	Water extraction of whole fruit.	Aug. 21	11.83	.98	.83	.00	.52	1.00	.03	.510	60.8	53.3	7.5	.038	.015	.023	.0356	.3007	.0029	.0218	.0308
3597.....	Whole fruit ash.	do.								.484	45.4	39.0	6.4	.0492	.0136	.0356	.0050				
3602.....	Water extraction of whole fruit.	Aug. 27	12.67	.85	.87	.07	.38	.92	.07	.558	53.5	49.0	4.5								
3602.....	Whole fruit ash.	do.								.543	41.7	34.7	7.0	.043	.015	.038	.0021	.256		.0213	.0295

In Table 6 it will be seen that the water-extract sample was used for a partial ash analysis as well as for the organic work. The purpose in view was to ascertain whether the thorough extraction in boiling water to which the fruit was subjected would yield an ash which gave alkalinities like or different from the whole fruit when burned. Several analyses were made to ascertain the comparative content of phosphoric acid in the extract and in the whole fruit. The results differ so widely, both for alkalinities and phosphoric acid, that they do not support each other; that is, if the organic salts were calculated from the alkalinities of the whole fruit ashed, this would give results differing so widely as to be impossible of explanation, thus raising the question of correct methods of treating the sample. From careful checks made of our methods, however, by use of synthetic solutions the authors are convinced of the reliability of the results given by the water-extraction sample. It is possible that in ashing the whole fruit it was heated in such manner as to lose a portion of the alkali carbonates. The discrepancy is more marked as the fruit matures.

The fact that the attempt to determine chlorin in the water-extract sample gave results entirely too high has been noted in another section. The results for chlorin in the ashed samples are reasonably constant and have an important bearing on the occurrence of this element in supposedly sophisticated grape products, which will be discussed in a report on the experimental wines.

The results for potassium, sodium, calcium, and magnesium oxids are presented simply as data on the ash composition of pure and adulterated grape products, the application of which must await further investigation.

COMPARISON OF RESULTS ON JUICE AND WHOLE-FRUIT SAMPLES.

The results for the organic elements and the acid salts in the whole fruit samples are more readily compared from Table 7.

The figures given in this table are percentage results for weighed samples of whole fruit and percentage results for the 1912 juice samples calculated from Table 1. It will be noted that the results for sugar as a soluble constituent are noticeably less on the whole fruit samples. This is explained by the fact that the seeds, skins, and woody fiber of the fruit is a part of the whole-fruit sample, and results in lowering the percentage content of sugar because the juice extracted by pressure always carries a greater percentage of sugar than is found in the residue left as marc or pomace.

TABLE 7.—Comparison of sugar and acid content of juice samples and whole-fruit samples for 1912, compiled from Tables 1 and 6. (Hartmann, Eoff, and Ingle, analysts.)

[Results in per cent.]

SAMPLES FROM SANDUSKY, OHIO.

Variety and laboratory number of sample. ¹	Date analyzed.	Sugar as invert.		Total acid as tartaric.		Total tartaric acid.		Free tartaric acid.		Fixed acid other than tartaric.		Cream of tartar.		Tartaric acid to alkaline earths.	
		Juice.	Fruit.	Juice.	Fruit.	Juice.	Fruit.	Juice.	Fruit.	Juice.	Fruit.	Juice.	Fruit.	Juice.	Fruit.
Concord:															
3603.....	Sept. 4	8.19	7.23	1.82	1.83	0.89	0.82	0.45	0.16	1.15	1.34	0.48	0.73	0.06	0.09
3604.....															
3607.....		9.48	8.52	1.42	1.42	.79	.68	.42	.10	.81	1.05	.42	.66	.04	.14
3608.....															
3611.....	Sept. 12	10.72	9.82	1.24	1.31	.68	.86	.30	.14	.75	.81	.39	.74	.07	.13
3612.....															
3615.....	Sept. 17	11.44	10.49	1.08	1.16	.68	.71	.25	.03	.61	.80	.47	.71	.05	.12
3616.....															
3619.....	Sept. 24	13.28	12.58	1.00	1.06	.72	.68	.21	.00	.53	.69	.56	.78	.07	.07
3620.....															
3624.....	Oct. 1	13.85	12.43	.95	1.01	.72	.76	.17	.03	.51	.62	.58	.75	.09	.14
3625.....															
3630.....	Oct. 7	14.78	14.03	.92	1.05	.69	.74	.12	.00	.51	.62	.63	.91	.07	.02
3631.....															
3654.....	Oct. 16	14.82	.....	.88	.96	.64	.77	.04	.00	.54	.56	.72	.91	.05	.05
3655.....															
3674.....	Oct. 23	14.77	13.05	.87	.95	.62	.75	.00	.00	.52	.55	.76	.88	.01	.05
3675.....															
3686.....	Oct. 30	14.91	13.90	.87	.91	.69	.79	.08	.00	.47	.48	.69	.92	.07	.06
3687.....															
3694.....	Nov. 4	14.50	10.65	.88	.93	.82	.91	.16	.03	.39	.47	.77	.98	.05	.10
3695.....															
Catawba:															
3605.....	Sept. 4	3.48	3.29	3.56	3.15	1.16	.90	.76	.40	2.60	2.50	.38	.46	.10	.15
3606.....															
3609.....	Sept. 9	6.41	5.71	2.90	2.60	1.04	.86	.62	.29	2.07	2.02	.39	.52	.10	.16
3610.....															
3613.....	Sept. 12	8.89	8.07	2.36	2.17	.86	.99	.43	.34	1.71	1.51	.44	.63	.08	.15
3614.....															
3617.....	Sept. 17	9.85	8.51	2.01	2.01	.85	.77	.45	.14	1.37	1.55	.43	.59	.07	.15
3618.....															
3621.....	Sept. 24	10.72	9.64	1.65	1.64	.69	.72	.19	.06	1.21	1.24	.50	.66	.10	.15
3622.....															
3626.....	Oct. 1	12.01	11.02	1.54	1.55	.75	.71	.29	.06	1.01	1.18	.51	.63	.06	.15
3627.....															
3632.....	Oct. 7	12.93	11.72	1.43	1.47	.75	.78	.22	.06	.96	1.05	.57	.75	.08	.13
3633.....															
3656.....	Oct. 16	14.31	.....	1.25	1.30	.73	.85	.21	.16	.77	.79	.57	.72	.06	.12
3657.....															
3676.....	Oct. 23	14.01	13.26	1.19	1.27	.60	.75	.07	.07	.85	.86	.55	.72	.09	.11
3677.....															
3688.....	Oct. 30	15.31	13.81	1.13	1.21	.70	.79	.21	.06	.68	.79	.53	.77	.05	.13
3689.....															
3696.....	Nov. 4	15.54	11.61	1.19	1.17	.78	.84	.21	.17	.69	.67	.66	.80	.05	.06
3697.....															

SAMPLES FROM CHARLOTTESVILLE, VA.

Concord:															
3582.....	Aug. 2	4.96	5.56	2.37	2.20	1.15	1.22	0.39	0.52	1.59	1.33	0.84	0.73	0.10	0.12
3588.....															
3589.....	Aug. 7	9.05	7.83	1.79	1.68	1.01	1.04	.36	.28	1.10	1.03	.70	.79	.08	.13
3590.....															
3592.....	Aug. 13	10.40	9.75	1.24	1.28	.82	.87	.15	.06	.75	.81	.70	.85	.11	.14
3594.....															
3595.....	Aug. 21	12.70	11.83	.87	.98	.67	.83	.00	.00	.51	.52	.84	1.00	.00	.03
3597.....															
3600.....	Aug. 27	14.22	12.67	.75	.85	.72	.87	.02	.07	.33	.38	.79	.92	.07	.07
3602.....															

¹ While the juice and whole-fruit samples for each date are portions of one original field sample, they are necessarily given different numbers in the record. In this table both numbers are entered; the first in each case is the juice sample and the second is the whole-fruit sample.

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WM. A. TAYLOR, Chief

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CEREAL EXPERIMENTS IN MARYLAND AND VIRGINIA.

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INTRODUCTION.

Experiments with cereals have been conducted cooperatively since 1904 at College Park, Md., by the Maryland Agricultural Experiment Station and the Office of Cereal Investigations.¹ Similar experiments have been conducted by the Office of Cereal Investigations on the Arlington Farm, Rosslyn, Va., since 1907.² These experiments have consisted mainly of varietal tests and extensive breeding operations with the most important winter cereals. This bulletin is for the most part a report of the varietal tests. The varietal testing has

¹ The preliminary cereal work conducted at College Park, Md., prior to 1907 was under the supervision of Mr. Mark Alfred Carleton, Cerealist of the Bureau of Plant Industry. Mr. H. A. Miller, a scientific assistant in the Office of Cereal Investigations, was in immediate charge. On October 1, 1907, when cooperative cereal investigations were begun with the Maryland station, Mr. V. M. Shoesmith, then agronomist at the station, was made collaborator. From the time of Mr. Shoesmith's resignation on January 1, 1908, Mr. C. W. Nash, assistant agronomist at the station, acted as collaborator to September 1, 1909. On the latter date Mr. N. Schmitz was appointed agronomist of the Maryland station, since which time he has been collaborator.

² The Arlington Farm is located in Virginia on the southern bank of the Potomac River, just opposite and to the west of the city of Washington, D. C. The experimental work with cereals has been under the direction of the men in charge of wheat, oat, and barley investigations in the Office of Cereal Investigations. From 1907 to 1912 Mr. H. B. Derr supervised the work with barley and wheat at the Arlington Farm. Since that time the work with these cereals has been in charge of Drs. H. V. Harlan and C. E. Leighty, respectively. Mr. C. W. Warburton has been in charge of the work with oats during practically the entire period. During the summer of 1908 Mr. T. B. Mackall assisted with the work at Arlington Farm; in the summers of 1909 and 1910 Mr. O. H. Saunders rendered similar service. The writer was appointed agent in the Office of Cereal Investigations on April 17, 1911, and scientific assistant in the same office on May 17, 1912. He has had direct charge of the work at Arlington Farm since the former date.

been confined largely to winter wheat, oats, and barley, although tests of several minor cereals, including winter rye, spelt, and emmer also have been conducted. In addition, some investigations have been conducted on the Arlington Farm with grain sorghum, buckwheat, proso, and spring varieties of wheat, oats, and barley. A preliminary report covering a portion of the cooperative cereal investigations at College Park was published in 1910.¹ In this bulletin a complete presentation of the work at College Park and at Arlington is made and such conclusions drawn as the results appear to warrant.

CEREAL PRODUCTION IN MARYLAND AND VIRGINIA.

The early history of the cultivation and production of cereal crops in Maryland and Virginia is quite meager, but it is known that their culture went hand in hand with the settlement of these colonies. In



FIG. 1.—Sketch map showing the areas in the eastern United States to which this bulletin applies. In the heavily shaded portion the results are generally applicable. Certain of the results are applicable in some parts of the lightly shaded portion, while other results are applicable in other parts.

the report of the United States Commissioner of Agriculture for the year 1872,² the following statements are made regarding the early history of the culture of cereals in the thirteen original States:

Wheat was first sown by Goswold on Cuttyhunk, one of the Elizabeth Islands, in Buzzard's Bay, as early as 1602, when he first explored the coast. In Virginia the first wheat appears to have been sown in 1611, and its culture continued to increase there till, in 1648, it is recorded that there

were several hundred acres of it. But it soon after fell into great disrepute as a staple crop, as the culture of tobacco was found to pay a great deal better. For more than a hundred years after it was but little cultivated in that colony.

But though the cultivation of wheat was begun almost simultaneously with the settlement of the several colonies, it did not attract very great attention for more than a century, Indian corn and, later, potatoes being relied upon for food to a much greater extent. . . . It is a matter of history that there never was a time in the eastern colonies when it was a sure and reliable crop, unless it be so now with our improved modes of culture and our better knowledge of the proper modes of tillage, deep plowing, and thorough drainage.

Rye and barley were also introduced and cultivated by the early settlers, and it soon became the almost universal practice to mix the meal of the former with Indian meal in the making of bread. It is known to have been the custom as early as 1648, and probably it began at a considerably earlier date, perhaps as early as 1630. Oats were also introduced at the same time with rye. Capt. Goswold raised them with other grains on one of the Elizabeth Islands, on the southern coast of Massachusetts, in 1602. Though much more extensively grown than rye, they appear to have been used chiefly as food for animals.

¹ Schmitz, Nickolas. Wheat—variety tests and diseases. Md. Agr. Exp. Sta. Bul. 147, p. 33-45. 1910.

² Flint, C. L. A hundred years of progress. In U. S. Com. Agr. Rpt., 1872, p. 280. 1874.

While it is known that these crops were grown in Virginia and Maryland since early colonial days, they did not come into prominence until the last half of the nineteenth century, when the invention of the thrashing machine and the self-binder greatly stimulated their production. To-day Virginia and Maryland are not great grain-producing sections as compared with the North-Central States, yet wheat, oats, barley, and rye are grown to a greater or lesser extent throughout these and adjoining States. Of the small grains, winter wheat has always been foremost in importance; in fact, its annual production is many times greater than that of all others combined.

During the 10-year period from 1905 to 1914, inclusive, the acreage and production of wheat in Maryland and Virginia have remained about stationary. The average production for the former State has been about 11,000,000 bushels, and for the latter about 9,000,000 bushels. The acreage in wheat in the two States, however, has been about the same. The fact that the average yield per acre for Virginia has been only slightly more than 12 bushels, as compared with about 16.5 bushels for Maryland, accounts for the greater production in the latter State.

During the same period the relative importance of oats, rye, and barley has been in the order named. Rye is grown entirely as a fall-sown crop, while oats and barley are grown from both spring and fall seeding.

PHYSICAL FACTORS.

Information with regard to the physical factors which may influence crop experiments is desirable for the interpretation of results. For that reason data are given on the soil and climatic conditions at College Park and at Arlington Farm.

SOILS.

The soil of that particular portion of the Maryland Agricultural Experiment Station farm on which the experiments here reported were conducted is classed by the United States Bureau of Soils as Sassafras sandy loam. It is a medium to fine brown sandy loam of sedimentary origin, with an average depth of about 10 inches. The subsoil consists of a slightly sandy or rather heavy yellow loam, usually 5 or more feet in depth. The subsoil is more retentive of water than is usual in this type of soil, so that this section is for the most part poorly drained. This general soil type is not difficult to cultivate and responds well to good treatment. It is well suited to grain growing.

The soil of the Arlington Farm consists of a very heavy clay loam, yellow to brown in color, ranging from 4 to 10 inches in depth. It is underlain by a stiff, plastic, red, gray, or purplish clay subsoil of

variable depth. It is known locally as brick clay. The general soil type in its natural condition is difficult to cultivate. The extensive and continued use of green-manuring crops, commercial fertilizers, and lime, with the installation of a complete system of tile drainage, has greatly improved its physical condition as well as eliminated to a large degree the lack of uniformity in productiveness. The texture has been improved, thus rendering it easier to cultivate and more congenial to plant growth. This soil probably would be classed as Susquehanna clay, a type that usually is not well adapted to grain growing.

CLIMATIC CONDITIONS.

Rainfall in the eastern half of the United States is not usually an important limiting factor in crop production. Other general physical phenomena, such as wind and evaporation, also are not of great importance; consequently they are not used so much as an index to crop production as in the semiarid areas. Soil fertility is one of the most important factors in crop production throughout all the older agricultural regions in the eastern United States.

The most serious climatic condition encountered in the experimental work with cereals at College Park and Arlington has been the occurrence of hot, humid, showery weather during the ripening period, causing the rapid development of rust, scab, and other diseases. This has been more particularly true with reference to winter wheat, as winter oats and barley usually escape because of earlier maturity. In some years short periods of drought undoubtedly affect these crops, but in general they are not of serious consequence.

In the pages which follow, data are given on the rainfall and temperature for the period from 1905 to 1914. These data were recorded at the Weather Bureau station in Washington, D. C., about 10 miles west of College Park and about 2 miles north of the Arlington Farm.

RAINFALL.

The annual and average precipitation by months at Washington, D. C., for the 10 crop years from July, 1904, to June, 1914, inclusive, are shown in Table I. Weather data are now recorded at Arlington Farm, but as these data are available only since October, 1910, it was deemed advisable to use the data in full from the Weather Bureau station in Washington.

The average annual precipitation at Washington for the 10 crop years from July, 1904, to June, 1914, inclusive, as shown in Table I, was 42.33 inches. For this period the maximum annual precipitation was 53.47 inches (1906-7), and the minimum, 33.22 inches (1910-11).

Table I shows that August is usually the wettest month, while November is the driest. The average annual precipitation at College

Park is about 4 inches less than at Washington. Considerable variation in the monthly distribution at the two points also occurs.

TABLE I.—*Monthly and average precipitation at Washington, D. C., for the ten 12-month periods (crop years) from July, 1904, to June, 1914, inclusive, with the total and monthly average for each period.*

[Data (in inches) from the records of the United States Weather Bureau.]

Month.	1904	1905	1906	1907	1908	1909	1910	1911	1912	1913	Average.
July.....	6.25	9.95	6.80	1.55	3.29	1.80	3.73	4.47	7.21	3.24	4.83
August.....	2.97	9.75	14.36	4.34	5.14	2.27	1.26	7.27	1.50	5.42	5.43
September.....	5.34	2.34	.60	7.15	4.65	3.42	2.15	2.03	5.86	2.41	3.60
October.....	2.35	2.30	5.71	2.12	1.71	.79	5.74	4.07	.65	3.37	2.88
November.....	2.20	1.03	1.63	4.16	.60	.89	2.28	3.85	1.54	2.20	2.04
December.....	3.33	5.39	3.23	4.20	3.63	3.39	2.64	3.34	4.12	2.29	3.56
	1905	1906	1907	1908	1909	1910	1911	1912	1913	1914	
January.....	3.59	3.11	2.54	3.45	2.84	4.39	2.92	2.82	2.85	4.60	3.31
February.....	2.55	2.14	2.31	3.98	3.11	2.20	1.92	2.70	1.37	3.05	2.53
March.....	3.31	4.62	2.79	2.45	4.76	.57	2.31	6.14	4.67	2.27	3.39
April.....	2.69	3.03	3.61	1.60	2.69	5.89	2.85	2.33	5.86	3.20	3.38
May.....	3.22	1.80	5.03	6.10	3.77	3.43	.87	4.84	4.55	1.72	3.53
June.....	4.52	5.89	4.86	1.73	3.82	4.77	4.55	4.36	1.81	2.32	3.86
Total...	42.32	51.35	53.47	42.83	40.01	33.81	33.22	48.22	41.99	36.09	42.33

TEMPERATURE.

A summary of the mean, maximum, and minimum temperatures for the 10 crop years from July, 1904, to June, 1914, inclusive, at Washington, D. C., is presented in Table II.

TABLE II.—*Annual and average mean, maximum, and minimum temperatures, by months, at Washington, D. C., for the ten 12-month periods (crop years) from July, 1904, to June, 1914, inclusive, with the annual mean and absolute maximum for each crop year.*

[Data (in °F.) from the records of the United States Weather Bureau.]

Month.	1904			1905			1906			1907			1908		
	Mean.	Max.	Min.	Mean.	Max.	Min.	Mean.	Max.	Min.	Mean.	Max.	Min.	Mean.	Max.	Min.
July.....	74.4	92	57	76.4	95	60	75.2	91	56	75.8	93	52	78.0	99	57
August.....	72.3	92	52	73.6	90	52	76.4	94	62	72.4	91	55	73.2	95	52
September.....	67.4	90	36	68.2	88	41	72.9	94	50	69.4	91	43	66.6	86	41
October.....	54.1	86	28	56.9	88	33	56.9	82	31	52.0	81	30	58.2	86	34
November.....	43.1	68	25	44.4	73	20	47.8	75	30	44.5	65	24	46.0	72	19
December.....	30.9	60	6	37.5	59	18	37.0	69	13	38.1	68	19	37.0	69	18
	1905			1906			1907			1908			1909		
January.....	29.8	65	-2	40.0	71	11	37.2	76	10	34.2	58	11	36.0	61	13
February.....	26.4	49	4	34.0	64	7	30.2	58	3	30.8	67	6	43.0	70	17
March.....	45.0	80	14	37.6	62	18	48.8	93	22	47.4	80	25	42.1	75	26
April.....	54.0	82	29	55.5	87	27	48.4	83	23	56.4	87	29	54.2	88	26
May.....	65.2	87	41	64.4	92	33	59.2	85	39	65.3	92	39	64.4	90	36
June.....	71.8	93	47	72.8	95	53	65.9	89	48	71.8	97	52	73.4	94	51
Annual:															
Mean.....	52.9			55.1			54.7			54.8			56.0		
Maximum.....		93			95			94			97			99	
Minimum.....			-2			7			3			6			13

TABLE II.—*Annual and average mean, maximum, and minimum temperatures, by months, at Washington, D. C.—Continued.*

Month.	1909			1910			1911			1912			1913			Average.		
	Mean.	Max.	Min.	Mean.	Max.	Min.	Mean.	Max.	Min.	Mean.	Max.	Min.	Mean.	Max.	Min.	Mean.	Max.	Min.
July.....	74.7	96	53	77.6	95	57	78.7	99	56	75.8	94	60	77.6	97	58	76.4	95.1	56.6
August.....	73.0	96	53	73.8	90	58	76.6	100	54	73.4	92	53	74.2	97	54	73.9	93.7	54.5
September.....	66.4	84	42	71.0	94	48	70.4	89	46	70.4	94	42	67.4	93	40	69.0	90.3	42.9
October.....	53.1	80	31	60.2	90	31	57.2	80	38	59.3	87	36	58.8	77	35	56.7	83.7	32.7
November.....	50.8	77	29	41.4	66	23	42.8	70	22	46.9	77	25	47.8	76	28	45.6	71.9	24.5
December.....	31.8	66	8	30.5	62	8	41.0	67	22	40.0	73	19	40.4	66	24	36.4	65.9	15.5
1910			1911			1912			1913			1914						
January.....	33.7	58	11	38.2	68	15	25.0	58	-13	43.6	68	24	38.6	72	7	35.6	65.5	8.7
February.....	34.7	68	8	37.0	68	21	31.0	56	7	36.4	68	13	30.1	59	-1	33.4	62.7	8.5
March.....	51.2	86	26	41.0	75	14	40.9	76	18	49.0	77	17	29.4	75	15	43.2	77.9	19.5
April.....	57.9	92	37	51.2	80	26	55.6	81	31	55.4	86	32	53.5	86	28	54.2	85.2	28.8
May.....	61.5	87	39	70.0	96	37	65.1	90	41	64.4	90	37	67.0	95	41	64.7	90.4	38.3
June.....	69.7	94	45	73.0	101	56	70.4	93	45	72.8	96	45	75.9	98	56	71.8	95.0	49.8
Annual:																		
Mean.....	54.9			55.4			54.6			57.3			55.1			55.1		
Maximum.....		96			101			100			96			98				
Minimum.....			8			8			-13			13			-1			

Table II shows that the highest average mean temperatures have been recorded in July and the lowest average means in February. The average mean temperature for the 10 crop years was 55.1° F. The variation from this average has been slight, the warmest crop year having an annual mean of 57.3° and the coolest 52.9°. During the 10 years the absolute maximum has exceeded 100° F. only once, and the absolute minimum has fallen below zero in only three years. The lowest temperature recorded during the period was in January, 1912, -13° F. The annual mean temperatures at College Park are almost invariably 1 degree lower than at Washington.

NATURE OF THE EXPERIMENTS.

The primary object in all the varietal tests at College Park and Arlington Farm has been to determine the relative yielding power of the different varieties. Attempts have been made also to improve the yield, quality of grain, and other important characters in some of the leading varieties by both mass and pure-line selection. The production of new varieties by hybridization also has been attempted. The work done along these latter lines has been too extensive to permit presentation within the limits of this bulletin.

Nursery experiments in which each variety is grown in short rows of uniform length, row space, and rate of seeding are also conducted, in addition to the regular varietal tests in field plats. The usual procedure has been that if a new variety is especially promising in the nursery it is advanced to the field-plat tests as soon as sufficient seed

is available. If a variety fails to give evidence of superior merit or adaptability after repeated trials in nursery rows, it is usually discarded, although sometimes it is retained for some character that may be of value for breeding purposes.

Many hundreds of varieties and strains from various sources have been tested in the nursery. These have included importations from many foreign countries, new and untried sorts, and numerous local varieties. After several trials in nursery rows most of them have failed to warrant more extensive tests. Only a small proportion has been grown in the plats.

The plat tests at College Park have included 107 varieties and strains of winter wheat, 13 of winter oats, 12 of winter barley, and several each of winter spelt and emmer. At Arlington Farm they have included 43 varieties and strains of winter wheat, 19 of winter oats, 56 of winter barley, 12 of winter rye, and 6 of winter spelt and emmer. A rate-of-seeding test with wheat has also been conducted at Arlington. With some of these cereals the varietal trials have not been of sufficient duration to be conclusive. With others some very reliable results have been obtained. In general, those varieties that were discarded, more especially those that were grown only two or three years, were mixtures of some of the varieties already in the tests or were decidedly inferior in some character or characters.

During the period of crop growth, rather complete notes are taken on the different varieties. The date of seeding, rate of seeding, date of emergence, and stand usually constitute the data recorded in the autumn. In the spring the winter survival (estimated), dates of heading, ripening, and harvesting, the percentage of smut and rust infection and of lodging, and the average height of plants are recorded. At harvest time samples of the heads and of the whole plants are taken and stored for reference and study.

A small separator, especially designed for the purpose, is used in thrashing. The total weight of the crop is obtained just before thrashing, and the weight of the thrashed grain immediately thereafter. After thrashing, the grain is fanned and the weight per bushel determined. The yield per acre in bushels is figured at the standard weight per bushel for each crop.

CONDITIONS OF THE PLAT EXPERIMENTS.

DIMENSIONS.

At College Park the varietal tests have been conducted almost exclusively on twentieth-acre plats ($10\frac{1}{2}$ feet by 208 feet). They lie in series running north and south, with 18-inch alleys between the plats in the series. The roadways dividing the series (or fields, as they are called at the Maryland station) are $16\frac{1}{2}$ feet in width.

At Arlington also most of the field tests have been conducted on twentieth-acre plats ($16\frac{1}{2}$ feet by 132 feet). During the earlier years of the work tenth-acre plats (33 feet by 132 feet), and also a few fortieth-acre plats ($8\frac{1}{4}$ feet by 132 feet), were used. These plats also lie in series running north and south, with 18-inch alleys between the plats within the series. The series are separated by roadways $19\frac{1}{2}$ feet in width.

TREATMENT AND CROPPING OF PLATS.

The cereal experiments at Arlington Farm have been conducted on land that is undergoing a system of soil renovation by the use of green-manure crops, stable manure, commercial fertilizers, and lime. Sufficient acreage has been available to allow the alternation of the cereals with other crops. By this method the mixing of varieties from volunteer plants is avoided, and there is opportunity to carry out the general scheme of soil improvement. In general, the cereals have followed crops of cowpeas or soy beans plowed under in late August or early September. This is usually the third green-manure crop to be plowed under during the 15 months that elapse between the two grain crops, as the latter are always immediately followed as well as preceded by cowpeas or soy beans with a crop of winter rye between the two legume crops.

In addition, a top-dressing of about 10 tons of stable manure per acre is applied to the rye during the winter. At seeding time 200 pounds of acid phosphate, containing about 14 per cent of phosphoric acid, are applied.

Immediately after plowing the plats are worked down with the disk and acme harrows and allowed to remain until seeding time, when a good seed bed is usually obtained by double disking and harrowing.

The seeding is done with an 8-foot single-disk drill. The disks are 8 inches apart, with no chains or other leveling or compacting device attached. After seeding, the plats receive no further treatment, except that just prior to harvesting they are rogued in order to keep the varieties as free as possible from mixtures. The harvesting is done with an ordinary grain binder. The bundles are shocked, placing from 12 to 14 in a shock, and are allowed to stand in the field until stored or thrashed. The grain in the shock usually is protected from birds and the weather by canvas shock covers.

The small-grain crops at College Park are included in a more or less definite rotation, in which no hay or grass crop is used. The scheme has been to grow corn two years, followed by wheat or other small grains two years, with supplementary crops of crimson clover and cowpeas for green-manuring purposes.

Manure and commercial fertilizers also are used to maintain the soil fertility. The former is used on the corn crop, while the latter

always is applied to the small-grain crop. At seeding time from 300 to 400 pounds per acre of the following mixture are applied:

	Pounds.
Acid phosphate (14 per cent).....	1,400
Muriate of potash.....	200
Tankage.....	300
Nitrate of soda.....	100

This fertilizer analyzes approximately 9 to 10 per cent phosphoric acid, 5 per cent potash, and 2 per cent nitrogen. It is applied just before seeding by drilling it across the plats. By this method a more nearly even distribution of the fertilizer is secured, thus greatly reducing the chances of experimental error.

The plats are prepared for seeding in much the same manner as those at Arlington Farm. The seeding, harvesting, and thrashing operations also are quite similar. A hoe drill having 9 hoes 7 inches apart is used in seeding the plats.

EXPERIMENTS WITH WINTER WHEAT.

VARIETAL TESTS.

The varietal tests of wheat conducted at College Park and Arlington Farm have been confined entirely to winter varieties. Since winter wheat is by far the most important and widely grown small-grain crop in Maryland and Virginia, naturally it has received the most attention in these experiments. It is well known that spring wheat can not be grown successfully in the Middle Atlantic States. Attempts to grow it have been made by experimenters and by farmers, but never with any real success.

DATA ON YIELDS.

The annual and average yields per acre, in bushels of 60 pounds, for the varieties tested at College Park from 1908 to 1914, inclusive, and at Arlington from 1910 to 1914, inclusive, are presented in Table III. A few varieties were grown in field plats at Arlington in 1909, but the results were very unsatisfactory, because of nonuniform soil conditions and injury by birds. It was deemed best therefore not to include them in the table, as they are not at all comparable to those obtained in succeeding years.

The varieties shown in Table III have been sown at the rate of 6 pecks per acre each year except in 1908 and 1909, when rates of 5 and 6½ pecks, respectively, were used at College Park. The date of seeding also has been quite uniform, ranging from October 5 to 15. At each point all the varieties usually are sown within a period of two or three days each year.

The 82 varieties and strains shown in the Maryland section of the table have been grown for periods of 2 to 7 years at College Park. In the fall of 1908, after one year's results had been obtained, 25

varieties were discontinued.¹ These do not appear in Table III. During the following years 40 additional varieties were discontinued and 20 new ones added.

TABLE III.—*Annual and average yields of varieties of winter wheat grown at the Maryland Agricultural Experiment Station (College Park) and at Arlington Farm, Va., for the years stated.*

COLLEGE PARK (82 VARIETIES).

Group and variety.	C. I. No. ²	Mary- land station No.	Yield per acre (bushels).							
			1908	1909	1910	1911	1912	1913	1914	Average.
SOFT RED WINTER.										
Awne'd, glumes glabrous, white:										
Mammoth Red.....	2008	-----	37.36	27.23	26.77	37.67	23.37	28.33	36.93	31.09
Bearded Purple Straw.....	1911	-----	32.93	27.13	29.17	39.87	24.13	24.67	38.77	30.95
Turkish Amber.....	195	-----	33.10	25.67	29.83	34.80	24.53	23.43	39.43	30.11
Lancaster ³	1945	-----	37.88	24.57	27.27	35.90	25.40	24.37	34.83	30.03
Dietz (Dietz Longberry).....	1981	-----	25.07	28.87	28.27	39.80	23.40	22.10	38.63	29.53
Dietz.....	95	-----	27.33	26.37	26.30	40.23	22.23	24.73	33.07	28.71
Gipsy.....	199	-----	34.23	19.57	32.57	38.43	17.93	24.17	29.37	28.04
Fishhead.....	1732	-----	27.60	20.83	28.57	36.53	21.67	21.57	39.00	27.97
Valley.....	92	-----	26.93	20.30	31.50	26.53	21.33	24.63	35.17	26.63
Reliable.....	189	-----	27.40	16.73	27.67	27.17	19.30	22.40	30.53	24.46
Silver Sheaf (Jones Silver Sheaf Longberry).....	2496	-----	36.97	17.17	28.47	25.73	16.17	9.93	28.00	23.21
Doub.....	348	-----	-----	-----	29.00	27.60	28.93	17.67	27.00	26.04
Rudy.....	349	-----	-----	-----	22.60	26.70	25.97	19.07	35.73	26.01
Fulcaster.....	352	-----	-----	-----	-----	29.20	19.90	27.40	36.87	28.34
Fulcaster (Acme).....	354	-----	-----	-----	-----	30.17	29.20	15.73	35.13	27.56
Stoner (Miracle).....	358	-----	-----	-----	-----	-----	27.87	16.20	32.33	25.47
Diamond Grit.....	1941	-----	36.97	17.60	28.00	29.77	8.77	-----	-----	24.22
Servia.....	1673	-----	36.46	16.93	29.47	-----	-----	-----	-----	27.62
Tuscan Island.....	1984	-----	35.69	22.20	27.47	-----	-----	-----	-----	27.45
Budapest.....	1739	-----	36.59	15.10	29.00	-----	-----	-----	-----	26.90
Missouri Bluestem ⁴	1910	-----	32.10	14.27	26.87	-----	-----	-----	-----	24.41
Nigger.....	1988	-----	-----	-----	34.80	37.70	-----	-----	-----	36.25
Skipper.....	227	-----	22.53	28.20	-----	-----	-----	-----	-----	25.37
Awne'd, glumes glabrous, brown:										
Mediterranean.....	1909	-----	34.53	20.87	25.37	40.10	16.60	25.77	35.00	28.32
Missouri Bluestem.....	1912	-----	31.87	19.87	32.80	28.17	28.60	21.77	34.67	28.25
Spade.....	1935	-----	35.69	20.60	27.80	28.63	26.13	17.67	37.80	27.76
Eclipse.....	105	-----	24.93	19.43	24.57	38.20	24.60	22.67	35.83	27.18
Rieti.....	1745	-----	32.27	16.70	31.67	29.50	28.63	15.90	35.00	27.10
Swamp.....	1934	-----	23.87	19.53	29.80	32.03	25.73	19.30	36.93	26.74
Rocky Mountain.....	1930	-----	33.64	18.97	26.37	26.73	27.60	-----	-----	26.66
Cox.....	1960	-----	37.88	16.80	28.33	25.00	-----	-----	-----	27.00
Onigara.....	1695	-----	26.00	18.93	17.43	-----	-----	-----	-----	20.79
Hybrid ⁵	3609	-----	36.72	19.20	-----	-----	-----	-----	-----	27.96
Awne'd, glumes pubescent, white:										
Pride of Genesee.....	1937	-----	33.73	18.80	25.57	28.13	21.70	12.27	29.57	24.54
Rural New Yorker.....	191	-----	32.10	17.33	31.67	28.30	24.07	-----	-----	26.69
Red Giant (Velvet Red Giant).....	1975	-----	34.03	13.47	26.00	-----	-----	-----	-----	24.50
Awne'd, glumes pubescent, brown:										
Japanese Velvet Chaff.....	1757	-----	34.28	13.87	21.33	-----	-----	-----	-----	23.16
Awneless, glumes glabrous, white:										
Fultz ⁶	84	-----	32.28	18.08	29.66	31.51	19.44	20.00	30.46	25.92
Fultz-Mediterranean.....	1980	-----	29.20	18.73	26.90	30.90	16.13	20.73	37.67	25.75
Four-Rowed Fultz.....	361	-----	-----	-----	-----	-----	23.03	19.10	24.33	22.15
Jersey Fultz.....	363	-----	-----	-----	-----	-----	-----	20.37	35.73	28.05
Purple Straw.....	1915	-----	34.13	22.40	30.00	26.57	13.87	-----	-----	25.39
Frostproof May.....	2007	-----	22.27	21.73	33.47	27.40	-----	-----	-----	26.22
Diminum.....	2191	-----	-----	21.87	33.27	41.40	-----	-----	-----	32.18
Oakley (Extra Early Oak- ley).....	1951	-----	22.41	23.33	26.70	-----	-----	-----	-----	24.15
Maryland Flint.....	1949	-----	24.53	19.07	-----	-----	-----	-----	-----	21.80

¹ Schmitz, Nickolas. Wheat—variety tests and diseases. Md. Agr. Exp. Sta. Bul. 147, p. 33–45. 1910.

² Cereal Investigations number.

³ Another variety having brown glumes is grown under this name. The one here reported appears to be identical with Fulcaster.

⁴ Two strains of this variety are grown.

⁵ The parentage of this hybrid is stated on page 18.

⁶ Average of 14, 19, 15, 12, 15, 13, and 13 check plats for the years 1908, 1909, 1910, 1911, 1912, 1913, and 1914, respectively.

TABLE III.—*Annual and average yields of varieties of winter wheat grown at the Maryland Agricultural Experiment Station (College Park) and at Arlington Farm, Va., for the years stated—Continued.*

COLLEGE PARK (82 VARIETIES)—Continued.

Group and variety.	C. I. No.	Mary- land sta- tion No.	Yield per acre (bushels).							Average.
			1908	1909	1910	1911	1912	1913	1914	
SOFT RED WINTER—continued.										
Awnless, glumes glabrous, brown:										
China.....	194		36.57	23.77	29.33	42.87	22.00	24.67	39.00	31.1
Currell (Currell Prolific).....	89		30.10	23.07	28.60	41.43	20.20	22.10	41.87	9.262
Red Clawson (Royal Red Clawson).....	188		33.50	23.03	27.27	35.50	20.60	25.87	36.67	28.92
Gill.....	1987		31.00	22.13	30.17	37.53	26.67	13.27	36.73	28.21
Beechwood (Beechwood Hybrid).....	1972		30.93	17.67	27.63	34.87	16.97	21.07	31.83	25.85
Poole.....	198		25.40	15.17	27.47	27.37	19.83	11.57	34.93	23.11
Red Wave.....	351					23.10	18.43	15.00	31.00	21.88
Beechwood (Beechwood Hy- brid) (Ky.).....	364							22.67	36.73	29.70
Boughton.....	1993		38.26	17.30	28.13	40.17	14.00			27.56
Red Clawson (Early Red Clawson).....	1922		33.07	18.40	26.73	33.17	20.93			26.46
Michigan Amber.....	1969		35.43	14.73	29.40	30.20	15.50			25.05
Jones Red Chief (Jones Early Red Chief).....	2498		26.40	21.73	28.57	25.97	21.03			24.54
Poole.....	1979		33.20	14.73	33.00	35.93				29.22
Harvest King.....	193		32.80	20.30	32.93	27.30				28.33
Red Chief (Early Red Chief) Arcadian (Early Arcadian).....	350				34.53	28.10	24.40			29.01
New York No. 10.....	1749		25.47	10.00						17.74
Rochester (Rochester Red).....	347				29.43	25.20				27.32
Awnless, glumes pubescent, white:	355					25.93	15.77			20.85
Jones Winter Fife.....	1933		37.23	16.67	30.67	28.03	19.40			26.40
Mealy.....	1925		37.75	14.60	35.20	25.57				28.28
Canadian Hybrid.....	1747		37.75	16.33	29.93	26.80				27.70
Hybrid ¹	3618		34.92	16.37						25.65
SOFT WHITE, OR AMBER WINTER.										
Awned, glumes glabrous, white:										
New Amber Longberry.....	1973		34.92	18.33	31.37	27.70	15.00			25.60
Oatka (Oatka Chief).....	1985				29.87	40.20				35.04
Awned, glumes glabrous, brown:										
Klondike.....	356						10.03	19.93	35.57	21.84
Genesee Giant (Early Gene- see Giant).....	1744		29.20	17.80	33.10	24.70	14.77			23.91
Awned, glumes pubescent, white:										
Bearded Winter Fife.....	1942		39.41	20.63	27.87	43.73	15.50	25.10	34.67	29.56
Awned, glumes pubescent, brown:										
Bearded Velvet Chaff.....	2500		35.73	17.90	31.00	14.90				24.88
Awnless, glumes glabrous, white:										
Martin Amber.....	1974		28.67	16.67	33.73	27.17	9.33	23.00	31.67	24.32
Awnless, glumes glabrous, brown:										
Dawson Golden Chaff.....	1733		37.49	19.87	33.57	26.47	14.27	23.40	35.13	27.17
Gold Coin.....	353					23.83	18.67	11.47	32.70	21.67
Dawson Golden Chaff.....	187		30.83	17.73						24.28
Massey.....	357						23.33	16.43		19.88
HARD RED WINTER.										
Awned, glumes glabrous, white:										
Malakof.....	365							23.43	34.57	29.00
Turkey.....	1782		30.30	14.27	25.17					23.25
Awnless, glumes pubescent, white: Haynes ²	1505			14.67	23.37					19.02

¹ The parentage of this hybrid is stated on page 18.² Spring wheat grown from fall seeding.

TABLE III.—*Annual and average yields of varieties of winter wheat grown at the Maryland Agricultural Experiment Station (College Park) and at Arlington Farm, Va., for the years stated—Continued.*

ARLINGTON FARM, VA. (43 VARIETIES).

Group and variety.	C. I. No.	Yield per acre (bushels).					
		1910	1911	1912	1913	1914	Average.
SOFT RED WINTER.							
Awned, glumes glabrous, white:							
Lancaster ¹	1945	31.00	28.80	29.08	26.50	33.30	29.74
Mammoth Red.....	2008	29.17	25.30	29.20	25.20	28.20	27.41
Dietz (Dietz Longberry) ²	1981	31.49	25.20	28.34	21.10	28.20	26.87
Hybrid ³	3608	29.66	21.20	31.67	19.07	25.30	25.38
Bearded Purple Straw.....	1911	25.03	20.10	28.67	23.20	22.30	23.86
Hybrid ³	3611	20.00	20.70	21.60	15.70	24.70	20.54
Stoner (Miracle).....	2890		25.20	30.17	22.00	32.30	27.42
Hybrid ³	3617		21.70	34.67	21.80	27.80	26.49
Fishhead.....	1732	30.83	17.30	27.33	21.70		24.29
Hybrid ³	3612		13.80	20.27	19.50	24.50	19.52
Silver Sheaf (Jones Silver Sheaf Longberry).....	2196				17.50	22.30	19.90
Fulcaster (Acme).....	3115		19.70	24.33			22.02
Awned, glumes glabrous, brown:							
Rocky Mountain.....	1930	26.83	25.80	31.50	26.20	26.30	27.33
Missouri Bluestem.....	1912	22.17	28.60	32.08	22.50	28.70	26.81
Hybrid ³	3609	24.33	14.70	32.53	18.01	23.30	22.57
Do. ³	3614		16.80	30.07	19.20	31.30	24.34
Do. ³	3613		12.00	22.27	19.70	31.20	21.29
Rocky Mountain.....	3638			28.67	19.30	24.70	24.22
Similar to C. I. No. 3614.....	3640				17.60		
Awned, glumes pubescent, white:							
Hybrid ³	3616	25.67	20.00	29.67	16.10	31.00	24.49
Virginia (hybrid) ³	3277		24.50	35.15	21.00	21.50	25.54
Awnless, glumes glabrous, white:							
Purple Straw.....	1915	24.59	25.80	37.17	34.70	38.20	32.09
Fultz.....	1923	37.65	25.20	31.22	22.70	29.10	29.17
Purple Straw.....	1957	26.00	31.30	33.08	24.20	30.80	29.08
Maryland Flint.....	1949	22.33	32.30	29.08	23.50	23.70	26.18
Fultz-Mediterranean.....	1980	18.00	21.70	28.83	19.20	22.50	22.05
Kentucky.....	4B-383			29.83	23.30		26.57
Awnless, glumes glabrous, brown:							
Poole.....	1979	31.66	24.30	31.92	26.60	29.20	28.74
Hybrid ³	3610	30.33	16.70	29.20	22.00	21.00	23.85
Michigan Amber.....	1969		28.00	28.83	21.00	21.00	24.71
Currell (Currell Prolific).....	3326				20.20	30.30	25.25
China.....	180				21.80	20.00	20.90
Awnless, glumes pubescent, white:							
Jones Winter Fife.....	1933	26.67	22.80	24.00	24.70	24.70	24.57
Hybrid ³	3618	20.00	22.50	30.55	20.80	22.20	23.21
SOFT WHITE OR AMBER WINTER.							
Awned, glumes glabrous, white:							
New Amber Longberry.....	1973		26.50	29.50	22.70	29.50	27.05
Awned, glumes glabrous, brown:							
Genesee Giant (Early Genesee Giant).....	1744	24.17	20.30	30.67	28.40	32.50	27.21
Awned, glumes pubescent, white:							
Bearded Winter Fife.....	1942	30.00	26.60	36.42	24.90	23.30	28.24
Do.....	4204				22.80	36.80	29.80
Awnless, glumes glabrous, white:							
Martin Amber.....	1974	25.67	21.90	31.50	20.00	23.70	24.55
Awnless, glumes glabrous, brown:							
Dawson Golden Chaff.....	1733	25.06	24.80	36.00	25.80	35.20	29.37
HARD RED WINTER.							
Awned, glumes glabrous, white:							
Kharkof (Acme Bred Kharkof).....	3615			22.27	16.20		19.24
Awnless, glumes glabrous, white:							
Power ⁵	1506	14.50					
DURUM.							
Berdiansk ⁶	1586	18.33	8.10	23.00	13.70		15.78

¹ Another variety having brown glumes is grown under this name. The one here reported appears to be identical with Fulcaster.² Average of 6, 8, 10, 18, and 13 check plats for 1910, 1911, 1912, 1913, and 1914, respectively.³ The parentage of these hybrids is stated on page 18.⁴ Kentucky station number.⁵ Spring wheats grown from fall seeding.

Of the 43 varieties grown at Arlington 36 were included in the tests of 1914. Those few that were discontinued in 1913 and previous years at Arlington did not yield well enough or were too inferior in quality to warrant their continuance in the plat tests. This also generally was true of the 65 varieties that have been eliminated at College Park. As the tests progressed it was necessary to discard some of the inferior sorts in order to make room for new and untried ones that appeared on the market.

MISCELLANEOUS DATA.

It is important in making a comparison of varieties to consider data other than those of yield. Table IV shows the average dates of heading and of ripening, average height, average yield of grain and of straw, and average weight per bushel for the varieties included in Table III.

Winter wheat at College Park and Arlington usually is fully headed by May 20, and ripe about one month later. The average dates of ripening, as given in Table IV, are remarkably uniform, being with few exceptions within a period of 3 or 4 days. There is no marked difference between the various groups, the one to which Fultz, Purple Straw, etc., belong probably being the earliest. The two earliest varieties grown at both Arlington and College Park are Fishhead (C. I. No. 1732) and Maryland Flint (C. I. No. 1949). It is generally believed that the early varieties yield more than the midseason and late ones, but if the early and late varieties in the several larger groups are compared, no definite correlation between earliness and yield is shown. Most of the best varieties in each group are those that are midseason in maturity. The China, the leading awnless variety at College Park, is one of the latest varieties, which is contrary to the belief that late varieties are not high yielders. However, this variety is very resistant to scab and rust, thus partially offsetting the disadvantage of late maturity.

The yields of straw in the winter-wheat varieties, as shown in Table IV, are quite variable. Those that rank high in yield of straw do not in all cases rank high in yield of grain. On the other hand, those that are high in yield of grain are not always heavy producers of straw.

The average weight per bushel at Arlington is higher than at College Park, because it is always determined after the grain is fanned, while at College Park it is usually determined as the grain comes from the thrasher. However, those varieties which have been best at Arlington in quality of grain, as determined by weight per bushel, have been best at College Park also, as a rule.

TABLE IV.—*Miscellaneous data for varieties of winter wheat grown at the Maryland Agricultural Experiment Station (College Park) and at Arlington Farm, Va., for the periods stated.*

COLLEGE PARK (82 VARIETIES), 1908 TO 1914, INCLUSIVE.

Group and variety.	C. I. No.	Maryland station No.	Number of years grown.	Average date—		Average height.	Average yield per acre.		Average weight per bushel.
				Headed.	Ripe.		Grain.	Straw. ¹	
SOFT RED WINTER.									
Awne'd, glumes glabrous, white:									
Mammoth Red.....	2008	.....	7	May 21	June 22	Inches. 51	Bushels. 31.09	Pounds. 3,300	Pounds. 58.2
Bearded Purple	1911	.....	7	do	June 21	51	30.95	4,060	59.2
Turkish Amber.....	195	.....	7	do	June 22	51	30.11	3,650	58.8
Lancaster.....	1945	.....	7	do	do	51	30.03	3,900	58.7
Dietz (Dietz Longberry)	1981	.....	7	do	do	51	29.53	4,140	58.2
Dietz.....	95	.....	7	do	do	51	28.71	3,660	59.2
Gipsy.....	199	.....	7	May 23	do	51	28.04	3,870	58.3
Fishhead.....	1732	.....	7	May 15	June 21	48	27.97	3,440	58.7
Valley.....	92	.....	7	May 21	June 23	50	26.63	3,500	58.1
Reliable.....	189	.....	7	May 22	June 22	49	24.46	3,470	56.9
Silver Sheaf (Jones Silver Sheaf Longberry).....	2496	.....	7	May 23	do	49	23.21	3,130	56.4
Doub.....	348	.....	5	May 20	do	49	26.04	2,310	60.1
Rudy.....	349	.....	5	May 22	June 23	47	26.01	2,310	57.8
Fulcaster.....	352	.....	4	do	June 22	51	28.34	2,350	59.4
Fulcaster (Acme).....	354	.....	4	do	June 23	50	27.56	2,310	60.1
Stoner (Miracle).....	358	.....	3	do	June 22	53	25.47	2,320	59.5
Diamond Grit.....	1941	.....	5	May 23	June 24	48	24.22	3,000	58.0
Servia.....	1673	.....	3	May 21	do	45	27.62	4,100	53.6
Tuscan Island.....	1984	.....	3	May 19	June 21	50	27.45	3,640	54.7
Budapest.....	1739	.....	3	May 20	June 22	46	26.90	3,070	55.3
Missouri Bluestem.....	1910	.....	3	May 19	June 24	49	24.41	3,510	53.4
Missouri Bluestem.....	1910	.....	2	May 22	June 23	49	36.35	2,760	61.5
Nigger.....	1988	.....	2	May 19	do	52	25.37	2,400	53.5
Skipper.....	227	.....	2	May 19	do	52	25.37	2,400	53.5
Awne'd, glumes glabrous, brown:									
Mediterranean.....	1909	.....	7	May 20	June 22	49	28.32	3,650	57.5
Missouri Bluestem.....	1912	.....	7	May 22	do	48	28.25	3,570	57.5
Spade.....	1935	.....	7	May 20	do	48	27.76	3,510	56.5
Eclipse.....	105	.....	7	May 21	do	49	27.18	3,650	56.4
Rieti.....	1745	.....	7	do	do	48	27.10	3,400	55.5
Swamp.....	1934	.....	7	May 22	June 23	48	26.74	3,630	57.8
Rocky Mountain.....	1930	.....	5	May 19	June 22	50	26.66	3,530	57.5
Cox.....	1960	.....	4	May 20	do	45	27.00	2,770	56.6
Onigara.....	1695	.....	3	May 13	June 21	42	20.79	2,020	53.8
Hybrid.....	3609	.....	2	May 20	June 23	47	27.96	4,250	54.2
Awne'd, glumes pubescent, white:									
Pride of Genesee.....	1937	.....	7	May 23	do	47	24.54	3,220	57.6
Rural New Yorker.....	191	.....	5	May 21	do	50	26.69	3,770	57.9
Red Giant (Velvet Red Giant).....	1975	.....	3	do	June 21	44	24.50	3,120	53.6
Awne'd, glumes pubescent, brown:									
Japanese Velvet Chaff.....	1757	.....	3	May 19	June 23	47	23.16	2,890	55.1
Awnless, glumes glabrous, white:									
Fultz.....	84	.....	7	May 21	June 21	49	25.92	3,640	56.8
Fultz-Mediterranean.....	1980	.....	7	May 19	do	45	25.75	2,960	57.2
Four-Rowed Fultz.....	361	.....	3	May 21	June 20	44	22.15	2,310	57.0
Jersey Fultz.....	363	.....	2	May 24	June 22	47	28.05	2,720	59.8
Purple Straw.....	1915	.....	5	May 19	do	49	25.39	3,680	56.9
Frostproof May.....	2007	.....	4	do	June 21	47	26.22	4,140	58.6
Diminum.....	2191	.....	3	May 21	June 23	47	32.18	2,760	57.0
Oakley (Extra Early Oakley).....	1951	.....	3	May 17	June 20	48	24.15	3,510	54.8
Maryland Flint.....	1949	.....	2	May 16	June 21	48	21.80	4,780	52.3

¹ Data on yield of straw were not taken in 1908; hence, the average yield is for one year less than the total number of years the variety was grown. Varieties introduced after 1908, for which data on yield of straw are available for the full number of years, are noted in the table.

² Data on yield of straw taken each year the variety was grown.

³ Data on weight per bushel for one year less than the full number the variety was grown.

TABLE IV.—*Miscellaneous data for varieties of winter wheat grown at the Maryland Agricultural Experiment Station (College Park) and at Arlington Farm, Va., for the periods stated—Continued.*

COLLEGE PARK (82 VARIETIES), 1908 TO 1914, INCLUSIVE—Continued.

Group and variety.	C. I. No.	Mary- land station No.	Num- ber of years grown.	Average date—		Average height.	Average yield per acre.		Average weight per bushel.
				Headed.	Ripe.		Grain.	Straw.	
SOFT RED WINTER— continued.									
Awnless, glumes gla- brous, brown:						<i>Inches.</i>	<i>Bushels.</i>	<i>Pounds.</i>	<i>Pounds.</i>
China.....	194	7	May 24	June 24	51	31.17	3,980	58.0	
Currell (Currell Prolific).....	89	7	May 20	June 21	50	29.62	3,580	57.9	
Red Clawson (Royal Red Clawson).....	188	7	do.....	June 22	47	28.92	3,270	57.5	
Gill.....	1987	7	do.....	June 21	47	28.21	3,240	56.9	
Beechwood (Beech- wood Hybrid).....	1972	7	May 21	June 22	49	25.85	3,470	56.0	
Poole.....	198	7	May 20	do.....	48	23.11	3,110	56.3	
Red Wave.....	351	4	May 24	June 23	46	21.88	1 2,600	57.3	
Beechwood (Beech- wood Hybrid) (Ky.).....	364	2	May 23	June 21	48	29.70	1 3,910	59.5	
Boughton.....	1993	5	May 20	do.....	50	27.57	3,680	2 54.2	
Red Clawson (Early Red Clawson).....	1922	5	May 19	do.....	49	26.46	3,400	55.7	
Michigan Amber.....	1969	5	do.....	do.....	49	25.05	3,460	2 55.1	
Jones Red Chief (Jones Early Red Chief).....	2498	5	May 21	June 23	45	24.54	3,070	54.3	
Poole.....	1979	4	do.....	June 22	48	29.22	3,650	54.7	
Harvest King.....	193	4	May 20	June 23	47	28.33	2,820	56.5	
Red Chief (Early Red Chief).....	350	3	May 22	June 22	49	29.01	1 3,690	56.0	
Arcadian (Early Arcadian).....	1749	2	May 20	June 23	43	17.74	3,600	2 44.4	
New York No. 10.....	347	2	May 21	June 22	45	27.32	1 2,610	58.8	
Rochester (Roch- ester Red).....	355	2	May 23	June 23	48	20.85	1 3,130	58.3	
Awnless, glumes pu- bescent, white:									
Jones Winter Fife.....	1933	5	May 22	June 24	48	26.40	3,180	56.0	
Mealy.....	1925	4	May 20	June 22	45	28.28	3,270	53.5	
Canadian Hybrid.....	1747	4	May 22	June 24	46	27.70	3,280	55.4	
Hybrid.....	3618	2	May 23	June 23	46	25.65	3,200	2 53.2	
SOFT WHITE OR AMBER WINTER.									
Awned, glumes gla- brous, white:									
New Amber Long- berry.....	1973	5	May 24	June 24	53	25.26	3,480	56.0	
Oatka (Oatka Chief).....	1985	2	May 25	June 26	49	35.04	1 3,940	3 59.5	
Awned, glumes gla- brous, brown:									
Klondike.....	356	3	May 26	June 24	46	21.84	1 2,860	56.2	
Genesee Giant (Early Genesee Giant).....	1744	5	May 22	June 23	47	23.91	3,310	55.2	
Awned, glumes pubes- cent, white:									
Bearded Winter Fife.....	1942	7	do.....	June 22	48	29.56	3,370	57.8	
Awned, glumes pubes- cent, brown:									
Bearded Velvet Chaff.....	2500	4	May 23	June 24	43	24.88	2,480	56.5	
Awnless, glumes gla- brous, white:									
Martin Amber.....	1974	7	May 26	do.....	48	24.32	3,390	58.2	

¹ Data on yield of straw taken each year the variety was grown.² Data on weight per bushel for one year less than the full number the variety was grown.

TABLE IV.—*Miscellaneous data for varieties of winter wheat grown at the Maryland Agricultural Experiment Station (College Park) and at Arlington Farm, Va., for the periods stated—Continued.*

COLLEGE PARK (82 VARIETIES), 1908 TO 1914, INCLUSIVE—Continued.

Group and variety.	C. I. No.	Mary- land sta- tion No.	Num- ber of years grown.	Average date—		Aver- age height.	Average yield per acre.		Average weight per bushel.
				Headed.	Ripe.		Grain.	Straw.	
SOFT WHITE OR AMBER WINTER—continued.									
Awnless, glumes gla- brous, brown:									
Dawson Golden Chaff.....	1733	.....	7	May 22	June 22	<i>Inches.</i> 46	<i>Bushels.</i> 27.17	<i>Pounds.</i> 3,350	<i>Pounds.</i> 55.4
Gold Coin.....	353	.....	4	May 24	do.....	44	21.67	1 2,620	57.9
Dawson Golden Chaff.....	187	.....	2	May 19	do.....	44	24.28	2,480	54.2
Massey.....	357	.....	2	May 24	June 24	44	19.88	1 3,400	57.8
HARD RED WINTER.									
Awned, glumes gla- brous, white:									
Malakof.....	365	.....	2	May 23	June 21	51	29.00	1 4,020	60.7
Turkey.....	1782	.....	3	May 18	June 20	45	23.25	3,230	52.3
Awnless, glumes pu- bescent, white:									
Haynes.....	1505	.....	2	May 24	June 26	49	19.02	1 3,930	52.1

ARLINGTON FARM, VA. (43 VARIETIES), 1910 TO 1914, INCLUSIVE.

Group and variety.	C. I. No.	Number of years grown.	Average date—		Average height. ³	Average yield per acre.		Average weight per bushel.
			Headed. ³	Ripe.		Grain.	Straw. ³	
SOFT RED WINTER.								
Awned, glumes glabrous, white:								
Lancaster.....	1945	5	May 21	June 20	<i>Inches.</i> 48	<i>Bushels.</i> 29.74	<i>Pounds.</i> 4,390	<i>Pounds.</i> 59.9
Mammoth Red.....	2008	5	May 22	do.....	51	27.41	4,460	61.0
Dietz (Dietz Longberry).....	1981	5	May 23	June 19	49	26.87	3,780	61.1
Hybrid.....	3608	5	May 25	June 21	46	25.38	4,140	60.9
Bearded Purple Straw.....	1911	5	May 23	June 20	49	23.86	4,200	61.0
Hybrid.....	3611	5	May 26	June 22	43	20.54	3,780	60.9
Stoner (Miracle).....	2980	4	May 23	June 19	48	27.42	3,900	61.1
Hybrid.....	3617	4	May 26	June 22	44	26.49	4,530	61.0
Fishhead.....	1732	4	May 18	June 17	42	24.29	2,640	60.3
Hybrid.....	3612	4	May 26	June 22	46	19.52	3,960	57.1
Silver Sheaf (Jones Silver Sheaf Longberry).....	2496	2	do.....	June 21	51	19.90	5,600	60.0
Fulcaster (Acme).....	3115	2	May 24	do.....	46	22.02	2,960	60.0
Awned, glumes glabrous, brown:								
Rocky Mountain.....	1930	5	May 23	June 22	49	27.33	4,660	60.8
Bluestem.....	1912	5	May 24	June 23	49	26.81	4,610	60.7
Hybrid.....	3609	5	May 27	June 24	45	22.57	4,240	60.4
Do.....	3614	4	May 25	June 22	48	24.34	4,880	58.4
Do.....	3613	4	do.....	June 23	48	21.29	4,440	58.9
Rocky Mountain.....	3638	3	May 24	June 22	52	24.22	5,510	60.8
Similar to C. I. No. 3614.....	3640	1	May 21	do.....	46	17.60	2,380	60.0
Awned, glumes pubescent, white:								
Hybrid.....	3616	5	May 25	June 21	47	24.49	3,750	60.1
Virginia (hybrid).....	3277	4	May 27	June 24	47	25.54	3,940	60.6

¹ Data on yield of straw taken each year the variety was grown.² Data on weight per bushel for one year less than the full number the variety was grown.³ Dates of heading, height, and yield of straw are for four years only on all varieties grown for five years. In varieties grown for a less number of years these notes are for all years unless otherwise stated.⁴ For four years only.⁵ For three years only.

TABLE IV.—*Miscellaneous data for varieties of winter wheat grown at the Maryland Agricultural Experiment Station (College Park) and at Arlington Farm, Va., for the periods stated—Continued.*

ARLINGTON FARM, VA. (43 VARIETIES), 1910 TO 1914, INCLUSIVE—Continued.

Group and variety.	C. I. No.	Num- ber of years grown.	Average date—		Average height.	Average yield per acre.		Average weight per bushel.
			Headed.	Ripe.		Grain.	Straw.	
SOFT RED WINTER—contd.								
Awnless, glumes glabrous, white:					<i>Inches.</i>	<i>Bushels.</i>	<i>Pounds.</i>	<i>Pounds.</i>
Purple Straw.....	1915	5	May 19	June 18	46	32.09	4,320	61.4
Fultz.....	1923	5	May 22	do.....	48	29.17	4,200	60.8
Purple Straw.....	1957	5	May 17	do.....	49	29.08	4,590	61.3
Maryland Flint.....	1949	5	May 22	June 17	46	26.18	4,580	1 60.9
Fultz-Mediterranean..	1980	5	May 23	June 22	45	22.05	3,780	1 61.5
Kentucky.....	B-383	2	May 21	June 21	46	26.57	4,100	60.5
Awnless, glumes glabrous, brown:								
Poole.....	1979	2	May 22	June 22	48	28.74	4,510	60.4
Hybrid.....	3610	5	May 26	June 30	41	23.85	3,180	1 60.2
Michigan Amber.....	1969	4	May 23	June 21	50	24.71	4,610	60.8
Currell (Currell Pro- lific).....	3326	2	May 22	June 20	50	25.25	4,610	61.0
China.....	180	2	May 28	June 24	54	20.90	5,700	61.0
Awnless, glumes pubescent, white:								
Jones Winter Fife.....	1933	5	May 26	June 22	45	24.57	2 3,880	60.9
Hybrid.....	3618	5	do.....	do.....	45	23.31	3,840	1 60.4
SOFT WHITE OR AMBER WINTER.								
Awned, glumes glabrous, white:								
New Amber Longberry.....	1973	5	May 28	June 24	52	27.05	4,830	60.0
Awned, glumes glabrous, brown:								
Genesee Giant (Early Genesee Giant).....	1744	5	May 25	do.....	46	27.21	3,970	59.0
Awned, glumes pubescent, white:								
Bearded Winter Fife...	1942	5	May 23	June 21	46	28.24	4,210	60.2
Do.....	4204	2	May 24	do.....	47	29.80	4,610	60.3
Awnless, glumes glabrous, white:								
Martin Amber.....	1974	2	May 26	June 25	46	24.55	4,580	60.8
Awnless, glumes glabrous, brown:								
Dawson Golden Chaff..	1733	2	May 25	June 21	47	29.37	4,110	60.2
HARD RED WINTER.								
Awned, glumes glabrous, white:								
Kharkof (Acme Bred Kharkof).....	3615	2	May 27	June 24	39	19.24	2,980	61.0
Awnless, glumes glabrous, white:								
Power ³	1506	1	May 10	June 26	55	14.50	.....	.....
DURUM.								
Berdiansk ³	1586	4	2 May 25	do.....	2 40	15.78	2 2,150	61.0

¹ For four years only.² For three years only.³ Spring wheats grown from fallseeding.

HYBRIDS.

From Tables III and IV it will be noted that 11 of the wheats included in the tests at Arlington are hybrids. Two of these hybrids were also included in the varietal tests at College Park in 1908 and 1909, and are shown in Table III. These 11 hybrids are now prac-

tically all that remain of about 575, most of which have been grown at various times at College Park and Arlington. Of this number, 368 were made at Halstead, Kans., in 1900, by Mr. Deane B. Swingle. These were transferred to College Park in 1901, where about 172 additional hybrids were made by Mr. Mark Alfred Carleton in that year, thus bringing the number up to 540. They were grown and selected from year to year, the number being gradually reduced until the fall of 1907. At that time those that yet remained, together with about 35 other hybrids made by Mr. H. A. Miller in 1905 at College Park, were transferred to Arlington.

Finally, in the fall of 1909, when the total number had been reduced to less than 50, 11 of the most promising were included in the regular varietal tests. The parentage of the 11 selections from hybrids which are included in Table III is as follows:

C. I. No.	C. I. No.
3277, C. I. No. 1344 × Jones Winter Fife.	3612, Fultz × Eclipse.
3608, Diehl Mediterranean × Jones Winter Fife.	3613, Currell (Currell Prolific) × Dietz.
3609, Shirosawa × Jones Winter Fife.	3614, Currell × Eclipse.
3610, Jones Winter Fife × Dawson (Dawson Golden Chaff).	3616, C. I. No. 1344 × Jones Winter Fife.
3611, (Crimean × Onigara) × (Reddish White Bearded × Japanese No. 1).	3617, (Penquite Velvet Chaff × Zimmerman) × (Zimmerman × Turkey).
	3618, Jones Winter Fife × C. I. No. 1405.

C. I. Nos. 3277, 3608, 3609, 3610, 3616, and 3618 are selections from the hybrids made by Mr. Swingle at Halstead, Kans., in 1900; C. I. Nos. 3611 and 3617 are selections from those made in 1901 by Mr. Carleton at College Park, Md.; and C. I. Nos. 3612, 3613, and 3614 are selections from those made by Mr. Miller at the same place in 1905.

GROUPS OF SIMILAR VARIETIES.

For convenience in comparing the yields of similar wheats and to avoid confusion of varietal names in the future, the varieties in Tables III and IV have been grouped in accordance with some of the most obvious characters. In this grouping no attempts have been made to distinguish between white and amber kernels or between white and yellow or red and brown glumes. This classification is practically identical with the one published in Farmers' Bulletin 616.¹ It will be noted from Tables III and IV that practically all the varieties included in the tests are of the soft red and soft white groups. By far the greater number belong to the first group. Several of the hard red winter wheats have been tested, but with no marked success.

¹ Leighty, C. E. Winter-wheat varieties for the eastern United States. U. S. Dept. Agr. Farmers' Bul. 616, 14 p., 6 fig., 1914.

The wheats of this group are not adapted to the more humid areas of the United States.

SOFT RED WINTER.

Awned, glumes glabrous, white.—In order of yield, the leading varieties of this group that have been tested are the Lancaster, C. I. No. 1945; Mammoth Red, C. I. No. 2008; Dietz (Dietz Longberry), C. I. No. 1981; Bearded Purple Straw, C. I. No. 1911; and Stoner or "Miracle," C. I. No. 2980 and Maryland No. 358. These varieties are all quite similar (fig. 2). They are the most popular milling wheats



FIG. 2.—Heads of six varieties of winter wheat grown at the Maryland Agricultural Experiment Station and at Arlington Farm: 1, Dietz (Dietz Longberry); 2, Missouri Bluestem; 3, Purple Straw; 4, China; 5, Bearded Winter Fife; 6, Dawson Golden Chaff.

grown in the eastern United States. Probably the most widely advertised variety of this group in recent years is the Stoner or "Miracle" (Fulcaster). Great claims have been made for its free tillering habit and its heavy yields. Seed of the "Miracle" wheat was sold widely at extremely high prices, but in no instance did the results obtained justify the extravagant claims which were made. Data presented in another portion of this bulletin show that the "Miracle" variety possesses no greater tillering power than other similar wheats.

Awned, glumes glabrous, brown.—The Mediterranean, C. I. No. 1909, and the Missouri Bluestem, C. I. No. 1912, are the best varieties in this group. The Rocky Mountain, C. I. No. 1930, has been the leading variety at Arlington, but has not done so well at College Park.

The varieties Spade, C. I. No. 1935, and Eclipse, Maryland No. 105, are also among the best at College Park.

The Missouri Bluestem when first grown at Arlington was a mixture of a white-chaffed and a red-chaffed wheat. Selections were made, and in 1913 the best strain, a red-chaffed one, was substituted for the mixed stock in the tests. The white-chaffed strain was inferior and was discarded. The Missouri Bluestem variety, C. I. No. 1910, tested at College Park from 1908 to 1910, was identical with the white-chaffed strain just mentioned.

Awned, glumes pubescent, white.—Only five varieties included under this group have been tested, of which two were grown at Arlington and three at College Park. The Virginia, C. I. No. 3277, a hybrid variety, is of sufficient promise to warrant special mention. While it has not ranked unusually high in yield, the quality of grain in this variety is superior to that of the other four varieties.

Awnless, glumes glabrous, white.—The Fultz, C. I. No. 1923 and Maryland No. 84, one of the oldest and best known varieties of soft winter wheat, probably is the most valuable of the several varieties belonging to this group. However, at Arlington the Purple Straw, C. I. No. 1915, has outyielded it in a 5-year test by nearly 3 bushels per acre. Unfortunately, the Purple Straw was discontinued at College Park in 1912, and consequently data for only five years are available there. It has produced 32.09 bushels per acre, the highest average yield of any variety, at Arlington Farm during the five years from 1910 to 1914.

The Fultz-Mediterranean, C. I. No. 1980, a rather popular variety in Maryland and Virginia, has not compared favorably in yield with either Purple Straw or Fultz. At College Park it has yielded nearly as well as the Fultz. Of the 29 varieties that have now been tested for seven years at College Park the Fultz-Mediterranean ranks twenty-fifth in average yield per acre. The popularity of this variety is due largely to its short, stiff straw and its consequent freedom from lodging.

Awnless, glumes glabrous, brown.—The leading varieties of this group are the Poole, C. I. No. 1979; Currell (Currell Prolific), C. I. No. 3326; China, C. I. No. 180 and Maryland No. 194; and Red Clawson (Royal Red Clawson), Maryland No. 188. Of these the China has been the most promising at College Park, while the Poole takes the lead at Arlington. Regardless of group, the China has been the highest yielding wheat tested at College Park. This variety, however, has not yielded especially well at Arlington, where it has been included in the tests only since 1912. Just why a few varieties are particularly promising at College Park and of little value at Arlington, and vice versa, the writer can not say. The records of the China

and Purple Straw at the two places are among the best examples of this variation.

SOFT WHITE OR AMBER WINTER.

Awned, glumes pubescent, white.—The Bearded Winter Fife, C. I. No. 1942, has been the most promising of the so-called velvet-chaffed wheats tested at College Park and Arlington. A selection (C. I. No. 4204) which is quite similar to it has also been of particular promise at Arlington. Of the several varieties originated by Mr. A. N. Jones, of New York, that have been tested at College Park and Arlington, the Bearded Winter Fife is considerably the best.

Awnless, glumes glabrous, brown.—The Dawson (Dawson Golden Chaff) C. I. No. 1733, is the only representative of this group included in the tests. Among the soft white winter wheats this variety is of outstanding merit. It is one of the most popular varieties of winter wheat in the eastern United States. At Arlington it ranks third in average yield in a 5-year test and is first in yield of the awnless varieties. At College Park, however, it has not yielded so well, ranking eighteenth in average yield per acre among the 29 varieties that have been tested seven years. Two strains of this variety have been included in the tests at College Park.

HIGH-YIELDING VARIETIES.

The varieties which have been high in yield at College Park have not always been high in yield at Arlington, and vice versa. This is well shown in Table V, in which the average yields of the 10 best varieties at each place are shown, with the records of the same varieties at the other place for comparison. The integers in the columns headed "Rank" denote the rank of the variety among the total number in the test. The denominators of the fractions in these columns show the number of varieties grown in the same years as the variety in question, while the numerator shows the rank of that variety. Thus the China was grown only two years at Arlington, when it ranked thirty-second among 36 varieties that were grown the same two years.

Of the 82 varieties and strains which have been grown at College Park, the 10 highest in order of yield, as shown in Table V, are (1) China, (2) Mammoth Red, (3) Bearded Purple Straw, (4) Turkish Amber, (5) Lancaster, (6) Currell, (7) Bearded Winter Fife, (8) Dietz (C. I. No. 1981), (9) Red Clawson, and (10) Dietz (Md. No. 95). The difference in the 7-year average yield of China and Dietz (Md. No. 95) is 2.46 bushels. Of these 10 varieties, 9 are soft red and 1 (Bearded Winter Fife) is a white wheat. Of the red wheats, 6 (Nos. 2, 3, 4, 5, 8, and 10) are bearded, with glabrous white chaff; 3 (Nos. 1, 6, and 9), are beardless, with glabrous brown chaff. The one white-kerneled variety is bearded, with hairy white chaff. Of the 10

varieties, 7 are bearded and 3 beardless; 7 are white chaffed and 3 brown chaffed; and 9 have glabrous (smooth) and 1 pubescent (velvet) chaff.

TABLE V.—*The ten highest yielding varieties of wheat at the Maryland Agricultural Experiment Station (College Park) and at Arlington Farm, Va., arranged in order of yield, with the record of each in both locations.*

[The numerators of fractions in the columns headed "Rank" denote the rank of the variety for the years grown; the denominators indicate the number of varieties grown in those years.]

Name.	C. I. No.	Md. No.	At College Park.			At Arlington Farm.		
			Rank.	Number of years grown.	Average yield.	Rank.	Number of years grown.	Average yield.
College Park:								
China.....		194	1	7	31.17	$\frac{3}{8}$	2	26.90
Mammoth Red.....	2008		2	7	31.09	$\frac{2}{5}$	5	27.41
Bearded Purple Straw.....	1911		3	7	30.95	$\frac{4}{5}$	5	23.86
Turkish Amber.....		195	4	7	30.11			
Lancaster.....	1945		5	7	30.03	$\frac{2}{5}$	5	29.74
Currell.....		89	6	7	29.62	$\frac{3}{8}$	2	25.25
Bearded Winter Fife.....	1942		7	7	29.56	$\frac{3}{5}$	5	28.24
Dietz (Dietz Longberry).....	1981		8	7	29.53	$\frac{4}{5}$	5	26.87
Red Clawson.....		188	9	7	28.92			
Dietz.....		95	10	7	28.71			
Arlington Farm:								
Purple Straw.....	1915		$\frac{2}{5}$	5	25.39	1	5	32.09
Lancaster.....	1945		$\frac{2}{5}$	7	30.03	2	5	29.74
Dawson.....	1733		$\frac{1}{5}$	7	27.17	3	5	29.37
Fultz.....	1923		$\frac{3}{4}$	7	25.92	4	5	29.17
Purple Straw.....	1957					5	5	29.08
Poole.....	1979		$\frac{1}{5}$	4	29.22	6	5	28.74
Bearded Winter Fife.....	1942		$\frac{2}{5}$	7	29.56	7	5	28.24
Stoner.....	2980	358	$\frac{3}{4}$	3	25.47	8	4	27.42
Mammoth Red.....	2008		$\frac{2}{5}$	7	31.09	9	5	27.41
Rocky Mountain.....	1930		$\frac{2}{5}$	5	26.66	10	5	27.33

Of the 43 varieties and strains grown at Arlington, the 10 highest in order of yield (Table V) are (1) Purple Straw (C. I. No. 1915), (2) Lancaster, (3) Dawson, (4) Fultz, (5) Purple Straw (C. I. No. 1957), (6) Poole, (7) Bearded Winter Fife, (8) Stoner, (9) Mammoth Red, and (10) Rocky Mountain. The difference in the 5-year average yield between Purple Straw (C. I. No. 1915) and Rocky Mountain is 4.76 bushels. Of these 10 varieties, 8 have red grains and 2 (Nos. 3 and 7) have white grains. Of the red-grained varieties, 3 (Nos. 1, 4, and 5) are beardless, with glabrous white chaff; 3 (Nos. 2, 8, and 9) are bearded, with glabrous white chaff; 1 (No. 6) is beardless, with glabrous brown chaff; and 1 (No. 10) is bearded, with glabrous brown chaff. Of the two white-grained varieties, 1 (No. 3) is beardless, with glabrous brown chaff, and 1 (No. 7) is bearded, with hairy white chaff. Of the 10 varieties, 5 are bearded and 5 beardless; 7 are white chaffed and 3 are brown chaffed; and 9 have glabrous and 1 hairy chaff.

The Lancaster, Mammoth Red, and Bearded Winter Fife are the only varieties which appear among the 10 best at both College Park and Arlington. Of the other 7 among the 10 best at College Park the China has been grown only 2 years at Arlington and has been low in yield in both; Bearded Purple Straw has been eighteenth and Dietz

(Dietz Longberry) eleventh of 22 varieties grown in all 5 years; Currell has been grown only 2 years, with only a fair average yield; and Turkish Amber, Red Clawson, and Dietz (Md. No. 95) have not been included in the tests at Arlington. Of the remaining 7 in the 10 best at Arlington, Poole (C. I. No. 1979) was discarded at College Park in 1911 and Purple Straw and Rocky Mountain in 1912; Dawson is eighteenth and Fultz twenty-second among the 29 varieties grown all 7 years; Stoner has been grown only 3 years, with fair yields; and Purple Straw (C. I. No. 1957) has not been included in the tests at College Park.

TESTS OF SELECTIONS IN FIELD PLATS.

Many selections have been made from some of the leading varieties of winter wheat, the object being to develop superior strains. While the nursery work along this line has been rather extensive at both College Park and Arlington Farm, the number of pure lines that have been tested in field plats in comparison with the old strains is comparatively small. At College Park several of the high-yielding pure lines of the Fultz and Currell varieties were sown in twentieth-acre plats in the fall of 1910. Plats containing a mixture of a half dozen or more pure lines of each variety also were sown, as well as plats of the original unselected varieties for checks. Unfortunately, the Currell checks were not continued after 1911, so that only the yields of Currell in the regular varietal test in another field are available for comparison. The annual and average yields of these selections and of the original unselected varieties at College Park from 1911 to 1914 are shown in Table VI. At Arlington Farm pure-line selections were tested in field plats only in 1913 and 1914, so that data of sufficient value to report have not yet been obtained.

TABLE VI.—*Annual and average yields of pure lines of Fultz and Currell winter wheats at the Maryland Agricultural Experiment Station (College Park), 1911 to 1914, inclusive, with yields of the unselected varieties for comparison.*

Variety and strain.	Yield per acre (bushels).				
	1911	1912	1913	1914	Average.
Fultz (C. I. No. 1923 and Md. No. 84):					
Original stock.....	38.60	18.20	24.27	30.33	27.85
Mixture of pure lines.....	37.60	19.37	22.80	36.07	28.96
Plat 35 (1909 B. P.) ¹	36.33	24.20	21.83	34.67	26.76
Plat 42 (1909 B. P.).....	37.10	25.07	22.67	34.67	29.88
Plat 29 (1909 B. P.).....	38.70	22.57	24.07	29.67	28.75
Original stock.....	35.73	26.77	22.00	27.67	28.04
Currell (C. I. No. 3326 and Md. No. 89):					
Original stock.....	35.10	² 20.20	² 22.10	² 41.87	29.82
Mixture of pure lines.....	36.87	29.87	23.33	28.87	29.74
Plat 7 (1909 B. P.).....	37.43	28.70	23.57	32.00	30.43
Plat 5 (1909 B. P.).....	38.47	26.07	24.57	(³)	29.70
Plat 13 (1909 B. P.).....	35.03	30.73	25.47	29.77	30.25
Original stock.....	36.23				

¹ Breeding plat of 1909.

² Not comparable; grown in a different field. The Currell checks were discontinued after 1911.

³ Discontinued.

Table VI shows that two of the three pure lines of Fultz have given higher average yields for the four years than the original stock, one of them exceeding the original variety by nearly 2 bushels. The mixture of good pure lines has also exceeded the unselected original stock in average yield by about 1 bushel. In the one year (1911) when comparable yields of unselected Currell were obtained, two of the selections and the mixture of pure lines exceeded the original stock in yield. For the four years, the two pure lines which have been continued exceeded the mixture of pure lines by about one-half bushel. They have also exceeded the original stock, but, as previously stated, these yields are not really comparable.

From these results it appears that slight gains in yield are to be obtained by the selection of pure lines, even though, as in the present case, the original varieties apparently are quite pure.

RATE-OF-SEEDING TEST.

A test to determine the best rate of seeding for wheat was begun at Arlington Farm in 1911. Three varieties, Dietz (Dietz Longberry), Fultz, and Fulcaster (Acme), were sown at the rates of 4, 5, and 6 pecks each. In 1912 five additional varieties, Stoner, Martin Amber, Missouri Bluestem, Kharkof, and Purple Straw (C. I. No. 1957), were added to the test, the rates of seeding being the same as in the previous year. In 1913 and 1914 only four varieties, Dietz, Fultz, Stoner, and Martin Amber, were included; but the rates of seeding were increased to include 2, 3, 7, and 8 pecks. In 1911 and 1912 single twentieth-acre plats of each variety at each rate were sown. In 1913 and 1914 the tests were conducted in duplicate on fortieth-acre plats. The yields of grain from each variety at the different rates of seeding are shown in Table VII.

Table VII shows that the highest yield of the Dietz wheat for the four years from 1911 to 1914 was obtained from the 4-peck rate of seeding and the highest yield of the Fultz from the 5-peck rate. Only the 4, 5, and 6 peck rates were included in the test during all the years. The Stoner and Martin Amber wheats were sown at the 4, 5, and 6 peck rates in the three years from 1912 to 1914. Both these varieties have given slightly higher yields from the 4-peck rate than from either the 5-peck or 6-peck rate. The other varieties which were grown only in 1911 and 1912 vary but slightly in yield from the different rates of seeding.

The average for all varieties which have been grown at the 4, 5, and 6 peck rates from 1911 to 1914 shows a yield of 28.75 bushels from the 4-peck rate, 27.86 bushels from the 5-peck rate, and 26.45 bushels from the 6-peck rate. When the yields are shown on a strictly comparable basis by subtracting the quantity sown in each case from the average yield, the advantage of the lower rate is still further increased. The net average yield from the 4-peck rate is 27.75 bushels; from the 5-peck rate, 26.61 bushels; and from the 6-peck rate, 24.95 bushels.

Of the four varieties which were grown at rates of 2, 3, 4, 5, 6, 7, and 8 pecks in 1913 and 1914, the Dietz gave the highest yield from the 8-peck, the Fultz and Stoner from the 4-peck, and the Martin Amber from the 3-peck rate. The differences in yield from the various rates are slight, however, except that the 2-peck rate has given consistently lower yields.

TABLE VII.—*Annual and average yields per acre (bushels) obtained in a rate-of-seeding test with eight varieties of winter wheat at Arlington Farm, Va., 1911 to 1914, inclusive.*

Variety and year.	Rate of seeding (pecks per acre).						
	2	3	4	5	6	7	8
Dietz (Dietz Longberry), C. I. No. 1981:							
1911.....			31.30	21.40	18.80		
1912.....			28.00	24.50	22.67		
1913.....	18.90	19.90	16.80	18.70	19.40	17.40	19.70
1914.....	26.70	30.00	29.50	27.80	29.70	30.60	32.50
Average, 1913-14.....	22.80	24.95	23.15	23.25	24.55	24.00	26.10
Net average, 1913-14 ¹	22.30	24.20	22.15	22.00	23.05	22.25	24.10
Average, 1911-1914.....			26.40	23.10	22.64		
Net average, 1911-1914.....			25.40	21.85	21.14		
Fultz, C. I. No. 1923:							
1911.....			19.10	24.80	24.10		
1912.....			32.55	32.42	31.22		
1913.....	19.10	22.70	24.70	24.60	24.00	21.30	24.80
1914.....	29.70	33.00	39.00	37.70	36.20	37.40	37.90
Average, 1913-14.....	24.40	27.85	31.85	31.15	30.10	29.35	31.35
Net average, 1913-14.....	23.90	27.10	30.85	29.90	28.60	27.60	29.35
Average, 1911-1914.....			28.84	29.88	28.88		
Net average, 1911-1914.....			27.84	28.63	27.38		
Stoner (Miracle), C. I. No. 2980:							
1912.....			29.67	32.22	30.17		
1913.....	17.40	18.30	17.10	17.50	14.70	14.50	16.00
1914.....	26.90	30.70	32.80	28.90	29.70	30.90	29.80
Average, 1913-14.....	22.15	24.50	24.95	23.20	22.20	22.70	22.90
Net average, 1913-14.....	21.65	23.75	23.95	21.95	20.70	20.95	20.90
Average, 1912-1914.....			26.52	26.21	24.86		
Net average, 1912-1914.....			25.52	24.96	23.36		
Martin Amber, C. I. No. 1974:							
1912.....			34.92	31.83	28.83		
1913.....	18.40	19.70	19.00	17.20	17.40	12.40	14.70
1914.....	22.60	27.00	26.00	24.90	27.80	25.60	23.90
Average, 1913-14.....	20.50	23.35	22.50	21.05	22.60	19.00	19.30
Net average, 1913-14.....	20.00	22.60	21.50	19.80	21.10	17.25	17.30
Average, 1912-1914.....			26.64	24.64	24.68		
Net average, 1912-1914.....			25.64	23.39	21.10		
Fulcaster (Acme), C. I. No. 3115:							
1911.....			21.30	23.70	19.70		
1912.....			26.87	25.87	24.33		
Average.....			24.09	24.79	22.02		
Purple Straw, C. I. No. 1957:							
1912.....			29.67	29.25	28.78		
Missouri Bluestem, C. I. No. 1912:							
1912.....			27.67	25.07	23.33		
Kharkof, C. I. No. 3615:							
1912.....			20.67	22.50	22.27		
Summary of averages:							
3 varieties in 1911.....			23.90	23.30	20.87		
8 varieties in 1911.....			25.56	24.85	23.51		
4 varieties in 1912.....			19.40	19.50	18.37	16.40	18.80
4 varieties in 1913.....	18.45	20.15	19.40	19.50	18.37	16.40	18.80
4 varieties in 1914.....	26.47	30.17	31.82	29.82	30.85	31.12	31.02
All trials, 1913-14.....	22.46	25.16	25.61	24.66	24.61	23.76	24.91
Net average, 1913-14.....	21.89	24.41	24.61	23.41	23.11	22.01	22.91
All trials, 1911-1914.....			28.75	27.86	26.45		
Net average, 1911-1914.....			27.75	26.61	24.95		

¹ Actual yield less the quantity sown.

When the difference in the rate of seeding is considered, the net yields of the Dietz from the 3-peck and 8-peck rates were practically the same, 24.20 and 24.10 bushels, respectively, with the other rates of seeding averaging from 1 to 2 bushels lower. The net yields of the Fultz show that the 4-peck rate gave the best average result, 30.85 bushels, with a consistent reduction when less or more seed was sown, except that the 8-peck rate gave a higher net yield than any of the others except the 4-peck and 5-peck rates.

The Stoner gave the highest net yields from the 3-peck and 4-peck rates, 23.75 and 23.95 bushels, respectively. The net yields from the other rates of seeding were from 2 to 3 bushels lower. The highest net yield from Martin Amber, 22.6 bushels, was obtained from the 3-peck rate, with decidedly lower net yields from all the other rates except the 4-peck.

The average for all four varieties which were grown at the seven rates of seeding in 1913 and 1914 show slightly higher net yields from the 3-peck and 4-peck rates than from any of the others. The net average yields from these rates are 24.41 and 24.61 bushels, respectively. There is a constant reduction in the average net yield from higher and lower rates of seeding, except that the 8-peck rate gives a yield of 0.9 bushel higher than the 7-peck rate.

Although these tests have not been conducted long enough for the data to be conclusive, it appears that quite as good or perhaps slightly better yields may be obtained when wheat is sown at the rate of 3 or 4 pecks on fertile, well-prepared land than when sown at rates ranging from 5 to 8 pecks to the acre. As there is a decided saving of seed at the lower rates, these are to be preferred where conditions are similar to those existing on the Arlington Farm. It is not known how widely these results are applicable.

EXPERIMENTS WITH WINTER SPELT AND EMMER.

Spelt and emmer are closely related to wheat, but the spikelets do not break up in thrashing, as in wheat, the kernel remaining inclosed in the glumes. When the glumes are removed, the kernel is quite similar to that of wheat, not only in appearance but in composition. These grains are used chiefly as feed for domestic animals. Because the inclosing glumes give considerable bulk to the grain, the feeding value of spelt and emmer is about the same as that of oats or barley. These grains, particularly spelt, are not grown as generally in the South Atlantic States as experimental results seem to warrant.

Varietal tests of spelt and emmer have been conducted at College Park since 1908 and at Arlington since 1910. The tests at College Park have included five varieties of spelt and two varieties and one selection of emmer. Only two varieties of spelt, one of emmer, and the emmer selection, however, have been grown for the entire six

years from 1909 to 1914. At Arlington the tests have included four varieties and selections of spelt, one variety of emmer, and one emmer selection.

TABLE VIII.—*Tests of winter spelt and emmer at the Maryland Agricultural Experiment Station (College Park) and at Arlington Farm, Va., for the years stated.*

ANNUAL AND AVERAGE YIELDS.

Crop and variety.	C. I. No.	Yield per acre (bushels). ¹						
		1909	1910	1911	1912	1913	1914	Average.
AT COLLEGE PARK.								
Spelt:								
Alstrom.....	1773	52.53	59.27	70.27	69.73	54.27	73.33	63.23
Red Awnless.....	1772	43.07	61.87	66.27	72.00	66.13	69.73	63.18
Servia.....	1724	54.50	53.73					
Do.....	² 1774	22.67	48.20					
White Bearded.....	2481	52.57	50.00					
Emmer:								
Black Winter.....	2337	21.07	35.80	45.20	32.00	36.80	48.53	36.57
Black Winter selection.....	2337-1	21.47	33.47	47.07	36.67	34.13	³ 18.93	31.96
White.....	2101	12.53	30.80					
AT ARLINGTON FARM.								
Spelt:								
Alstrom.....	1773		88.00	50.67	78.20	51.33	102.20	74.08
Alstrom selection ⁴	3264			48.00	89.67	49.33	107.30	73.56
Red Awnless.....	1772		85.33	45.00	79.83	54.00	97.10	72.26
Servia.....	1724		57.00	40.67	74.67	48.33	87.20	61.69
Emmer:								
Black Winter.....	2337		34.33	11.67	30.67	20.50	14.50	22.33
Black Winter selection.....	2337-1		36.67	19.87	34.67	(⁵)		

MISCELLANEOUS DATA FOR THE PRINCIPAL VARIETIES FOR PERIODS OF FOUR TO SIX YEARS.

Crop and variety.	C. I. No.	Num- ber of years grown.	Average date—		Aver- age height.	Average yield per acre.		Aver- age weight per meas- ured bushel.
			Heading.	Ripe.		Grain. ¹	Straw.	
AT COLLEGE PARK.								
Spelt:					<i>In.</i>	<i>Bush.</i>	<i>Lbs.</i>	<i>Lbs.</i>
Alstrom.....	1773	6	⁶ May 23	⁶ June 23	42	63.23	⁶ 2,950	24.8
Red Awnless.....	1772	6	...do....	⁶ June 22	41	63.18	⁶ 3,030	24.0
Emmer:								
Black Winter.....	2337	6	⁷ May 31	⁸ June 28	45	36.57	⁶ 2,080	21.0
Black Winter selection.....	2337-1	6	...do....	⁸ June 27	45	31.96	⁶ 1,950	21.0
AT ARLINGTON FARM.								
Spelt:								
Alstrom.....	1773	5	May 26	June 23	41	74.08	3,100	30.5
Alstrom selection.....	3264	4	May 28	June 22	41	73.56	3,510	29.0
Red Awnless.....	1772	5	May 26	...do....	43	72.26	3,280	29.6
Servia.....	1724	5	...do....	...do....	43	61.69	3,290	26.9
Emmer:								
Black Winter.....	2337	5	May 31	June 26	41	22.33	1,940	25.5

¹ Bushels of 30 pounds each.

² Identical with Servia, C. I. No. 1724.

³ The low yield was due to a poor stand.

⁴ Identical with Alstrom, C. I. No. 1773.

⁵ Accidentally mixed with original strain in thrashing.

⁶ Data for five years only.

⁷ Data for three years only.

⁸ Data for four years only.

The methods of growing winter spelt and emmer are the same as for wheat. The date of seeding at College Park and Arlington has varied from October 5 to 15, the same dates as for winter wheat. The rate of seeding at both points has ranged from 8 to 12 pecks (60 to 90 pounds) per acre. These grains are rather difficult to sow with the ordinary drill, because of their bulky nature. The usual method has been to set the drill to sow about twice the quantity of seed that was really desired; that is, in order to sow 8 pecks per acre it was necessary to set the drill to sow 16 pecks.

Table VIII shows the annual and average yields in bushels of 30 pounds each of the spelts and emmers at College Park and at Arlington Farm, respectively. The average dates of heading and of maturity, height, yield of grain and of straw, and weight per bushel for the principal varieties at both localities are also shown.

Table VIII shows that decidedly better yields of spelt than of emmer have been obtained at both College Park and at Arlington Farm. The yields of spelt have been considerably higher at Arlington Farm than at College Park, while the yields of emmer at College Park have been higher than at Arlington Farm.

Table VIII also shows that spelt matures about June 22, or at the same time as wheat, and that emmer matures about 4 or 5 days later. The average height of plants of both spelt and emmer is about 3½ feet. The proportion of grain to straw is much greater than in wheat, but if the hull is removed from the kernel it is about the same as that of wheat. Owing to the large proportion of hull the weight per bushel is quite low. The average weight per bushel of emmer has been from 3 to 5 pounds less than that of spelt. The weight per bushel in each varies considerably from year to year, due to the fact that in some years a much greater proportion of the kernels thrashes free from the hull than in others.

These grains are very resistant to both stem and leaf rust; in fact, they are much more resistant to these diseases than wheat, oats, and barley. Of the two, emmer is believed to be the more resistant. No smut has ever been noted on spelt or emmer at either College Park or Arlington Farm.

LEADING VARIETIES.

The Alstroum, Red Awnless, and Servia spelts and the Black Winter emmer are the principal varieties of these grains which have been included in the tests at both College Park and Arlington Farm. Heads of all these varieties are shown in figure 3.

SPELT.

Alstroum.—The Alstroum spelt, C. I. No. 1773, was obtained by the Office of Cereal Investigations in 1901 from the Washington Agricultural Experiment Station, Pullman, Wash. This station intro-

duced it originally from Asia. It is an awnless, white-glumed, very stiff strawed variety. The head is $2\frac{1}{2}$ to 3 inches in length, erect, much more slender than that of wheat, and very compact. This variety has averaged 63.23 bushels to the acre in a 6-year test at College Park and 74.08 bushels in a 5-year test at Arlington Farm. It has given a higher average yield at both places than any other variety of spelt or emmer. A selection from Alstrom has been grown at Arlington Farm for 4 years, during which time it had an average yield 3 bushels higher than that of the original variety.



FIG. 3.—Heads of three varieties of spelt and one variety of emmer grown at the Maryland Agricultural Experiment Station and at Arlington Farm: 1, Alstrom spelt; 2, Red Awnless spelt; 3, Servia spelt; 4, Black Winter emmer.

Red Awnless.—The Red Awnless spelt, C. I. No. 1772, was also obtained by the Office of Cereal Investigations in 1901 from the Washington station. Like the Alstrom, it came originally from Asia. It is very similar to the Alstrom, except that the glumes are brownish red in color; hence the name. The average yield of the Red Awnless spelt was 0.05 bushel less than that of Alstrom at College Park and 1.82 bushels less at Arlington Farm.

Servia.—The Servia or “White Bearded” spelt, C. I. No. 1724, came originally from Serbia; hence the name. This variety was obtained at the Paris Exposition in 1900 by Mr. M. A. Carleton, Cerealist of the United States Department of Agriculture. This spelt is not unlike the Alstrom in appearance, except that it is bearded. The heads are slightly longer than those of the awnless varieties and

are less erect. The awns are slender, medium long, and very stiff. This character renders it more or less unpleasant to harvest and thrash. The average yield of the Servia spelt in a 5-year test at Arlington Farm was 12.39 bushels less than that of the Alstrom. This variety was discarded at College Park after a 2-year trial.

EMMER.

Black Winter.—The Black Winter emmer,¹ C. I. No. 2337, which has been grown in field plats at College Park and Arlington Farm was obtained in 1904 from a seed firm in Paris. Several earlier importations were grown in nursery rows only. The plant and head characters of emmer are quite different from those of spelt. The whole plant is larger, the leaves are wider, and the stem is larger in diameter. In the Black Winter (Black Velvet Winter) the heads are of a grayish black, velvety appearance; hence the name. The heads are quite large, bearded, compact, and much flattened. The awns are very long, heavy, and spreading. The yields of winter emmer at College Park have invariably been lower than those of spelt, the average for six years being 36.57 bushels as compared with 63.23 bushels for Alstrom spelt. A much greater difference in favor of spelt has been recorded at Arlington Farm, where the average yields were 22.33 bushels for emmer and 74.08 bushels for spelt.

EXPERIMENTS WITH WINTER RYE.

A varietal test of winter rye has been conducted at Arlington Farm since 1911. The rye varieties have not been grown in adjoining plats, but have been interspersed at more or less definite intervals throughout the series of wheat varietal plats. By this method the danger of cross-pollination among the rye varieties was greatly reduced. The test at Arlington Farm has included 12 varieties and selections of winter rye. No tests have been conducted at College Park.

The date of seeding for winter rye has varied from October 5 to 15. This is earlier than rye is usually sown in farm practice. However, the high yields that have been obtained each year by early sowing seem to indicate that the crop is usually sown too late to insure the best results. All varieties have been sown at the rate of 6 pecks to the acre.

The annual and average yields of these 12 varieties and selections for the four years from 1911 to 1914, inclusive, are shown in Table IX. The average dates of heading and of maturity, height, yield of grain and of straw, and weight per bushel for these varieties are also shown.

¹ For a more complete discussion of winter emmer, see Carleton, M. A., Winter emmer, U. S. Dept. Agr. Farmers' Bul. 466, 24 p., 8 fig., 1911.

TABLE IX.—*Tests of twelve varieties and selections of winter rye grown at Arlington Farm, Va., 1911 to 1914, inclusive.*

ANNUAL AND AVERAGE YIELDS.

Variety.	C. I. No.	Yield per acre (bushels).					
		1911	1912	1913	1914	Average.	
						1911-1914	1912-1914
Giant Winter ¹	30	21.70	37.45	36.30	36.10	32.89	36.62
Virginia Winter.....	128	24.30	31.61	27.20	38.60	30.43	32.47
Rimpau.....	126	22.30	33.84	25.70	35.50	29.34	31.68
Arlington Winter.....	127	15.60	32.68	26.80	41.10	29.05	33.53
Giant Winter ²	30	23.80	23.93	29.50	35.70	28.23	29.71
Mexican.....	108	14.30	35.54	28.20	31.80	27.46	31.85
Spring ³	73	5.50	30.59	36.10	35.50	26.92	34.06
Ivanof.....	34	12.30	37.68	21.40	34.50	26.47	31.19
Abruzzes.....	40	.....	34.56	37.90	35.20	.....	35.89
Henry.....	138	.....	32.00	34.30	26.80	.....	31.03
Giant Winter selection.....	30	.....	31.64	24.60	30.00	.....	28.75
Rimpau selection.....	126	.....	33.72	438.00	.....	.....	.....

MISCELLANEOUS DATA.

Variety.	C. I. No.	Number of years grown.	Average dates—		Average height.	Average yield per acre.		Average weight per bushel.
			Headed.	Ripe.		Grain.	Straw.	
					Inches.	Bushels.	Pounds.	Pounds.
Giant Winter ¹	30	4	May 7	June 18	59	32.89	3,700	55.1
Virginia Winter.....	128	4	May 5	do.....	61	30.43	3,570	54.6
Rimpau.....	126	4	May 12	June 26	57	29.34	4,250	52.8
Arlington Winter.....	127	4	May 7	June 20	62	29.05	4,350	55.4
Giant Winter ²	30	4	May 6	June 21	58	28.23	3,730	53.9
Mexican.....	108	4	May 1	June 16	59	27.46	3,560	54.9
Spring ³	73	4	May 5	June 18	58	26.92	3,360	55.5
Ivanof.....	34	4	do.....	June 19	58	26.47	2,990	54.4
Abruzzes.....	40	3	Apr. 28	June 16	63	35.89	4,660	54.7
Henry.....	138	3	Apr. 29	June 17	62	31.03	4,870	54.3
Giant Winter selection.....	30	3	May 3	June 20	60	28.75	3,710	54.3
Rimpau selection.....	126	2	May 11	June 27	57	35.86	3,150	53.0

¹ California strain.² Native strain.³ Grown prior to 1911 as a spring variety.⁴ Not comparable because of abnormal soil conditions.⁵ Data for 2 years only.⁶ Data for 1 year only.

As shown in Table IX, Giant Winter, C. I. No. 30, is the leading variety in yield of those tested four years. The Abruzzes, C. I. No. 40, which has been grown only three years, is only slightly lower in yield than the Giant Winter for that period (fig. 4). The lowest average yield for the four years was obtained from the Ivanof, C. I. No. 34. The differences in yield are slight, however, and a test for a longer period may show a quite different ranking.

According to the data in Table IX, the period between heading and ripening in rye is about 6 weeks. This is about 2 weeks longer than in wheat. The average date of heading in the 12 varieties and selections has varied from April 28 to May 12 and the average time of ripening from June 16 to 27. The average height of the plants has been about 5 feet. The average yield of straw of those tested four years has varied from 2,990 to 4,350 pounds. The data on yield

of grain and straw indicate that the proportion of grain to straw in rye is somewhat less than in wheat. The average weight per bushel has been about $1\frac{1}{2}$ pounds below the standard, with little variation between individual varieties.

LEADING VARIETIES.

The number of distinct varieties of rye is quite small. A large number of the so-called varieties have no particular distinguishing characters. It has been found at Arlington Farm that the several distinct varieties are becoming harder to recognize from year to year, despite the precautions that are taken to prevent cross-pollination.



FIG. 4.—Heads of four varieties of winter rye grown at Arlington Farm: 1, Giant Winter; 2, Virginia Winter; 3, Abruzzes; 4, Henry.

It is believed that eventually it will become necessary to discontinue all but the one variety that possesses the most desirable characters and then improve this one isolated variety. The different varieties grown at Arlington Farm during the past four years are all of more or less promise. For this reason the origin and a brief mention of each are given in the following paragraphs.

Giant Winter.—The Giant Winter rye, C. I. No. 30, was obtained from France through the Office of Foreign Seed and Plant Introduction in 1902. The three strains of this variety in Table IX are all from the same original stock. The California strain was obtained from that State in 1910, in order to compare it with the strain which had been grown continuously in the East since the importation of

the variety. In a 4-year test, the strain previously grown in California for eight years has outyielded the eastern-grown strain by slightly more than 4 bushels. Whether this increased yield was due entirely to the fact that it had been grown under California conditions for several years the writer can not say.

The Giant Winter selection was developed from an individual head selected at Arlington Farm. In a 3-year test it has given a lower average yield than the old strain. The Giant Winter is a very tall, large, and vigorous stiff-strawed variety. The heads are medium long, slightly flattened, compact, and tapering more or less toward the apex. The kernels are long, fairly plump, and of a brownish yellow color.

The Virginia Winter, C. I. No. 128, and Arlington Winter, C. I. No. 127, are very similar to the Giant Winter. The former is a pedigree strain that has been developed at Arlington, while the latter is a mass selection from a commercial variety that is grown extensively on the Arlington Farm for green-manuring purposes. Both have produced very satisfactory yields. The variety C. I. No. 73, originally a spring rye, is also quite similar to Giant Winter. This variety was obtained from Mr. F. W. Boehme, Geneva, Idaho. Only about 15 per cent of the plants survived the winter the first year it was sown at Arlington Farm. The next year and thereafter it behaved as a true winter variety. It is quite possible that the seed that was sown the first year contained a mixture of a winter rye, which accounted for the few plants that did not winterkill. The yield of this rye in succeeding years compared favorably with that of the other varieties.

Abruzzes.—The Abruzzes or Abruzzi rye, C. I. No. 40, was introduced into the United States from San Giovanni a Teduccio, near Naples, Italy, in 1904. This rye does not differ greatly in appearance from most of the varieties previously mentioned, yet when pure it can usually be recognized readily. It is the tallest of all the varieties that have been tested at Arlington Farm. The heads are long, nearly square, and well developed. They are less tapering than in most ryes, holding their width until quite near the tip. The kernels are large, plump, and of a dark-brown color. The quality of grain in this variety is probably the best of any that have been grown at Arlington Farm. Because of its tall, slender straw the Abruzzes is quite likely to lodge when grown on rich land. This variety is becoming quite popular in many sections in the South Atlantic States.

Mexican.—The Mexican variety, C. I. No. 108, was obtained from Tlaxcala, Mexico. In general appearance it is quite similar to the Giant or Virginia Winter type. However, the whole plant is less

vigorous, the stems are more slender, and the heads and kernels are both smaller. The kernels are yellow in color and usually quite well developed.

Ivanof.—The Ivanof rye, C. I. No. 34, was introduced into this country from Russia by Prof. N. E. Hansen in 1898. In general appearance and plant characters it is practically the same as the Mexican.

Rimpau.—The Rimpau rye, C. I. No. 126, was introduced from Germany in 1910. The seed was purchased from Mr. W. Rimpau, a noted German cereal breeder, Schlansted, Saxony, and was known as "Old Breeding." It is a rather more distinct variety than any of those previously mentioned. It is decidedly the latest maturing rye included in the tests at Arlington. The leaves are much broader than those of other varieties. Because of this character it is more frequently recommended than others where a hay variety is desired. The heads are drooping, very large, nearly square, and are borne upon a large but not very stiff straw. The kernels are medium long, broad, shrunken, and blue in color. The quality of grain in the Rimpau variety is inferior to that of any other included in the trials at Arlington. The shrunken condition of the kernel is apparently due more to an inherent characteristic of the variety than to environment.

The Rimpau selection is a pure line of this variety which was selected at Arlington Farm with the intention of improving the quality of grain, although no marked improvement was effected. The straw of this particular strain was quite weak, and for this reason it was discontinued.

Henry.—The original source of the Henry rye, C. I. No. 138, is not known. This rye when pure is quite different in appearance from any other here discussed and it usually can be identified readily. The heads are short and very broad at the base, giving them a spear-shaped appearance. The kernels are quite similar to those of the Abruzzes, except that they are a little lighter brown in color. In yield the Henry rye has been less satisfactory than the Giant or Virginia Winter.

EXPERIMENTS WITH WINTER OATS.

Fall-sown oats succeed much better than spring oats in southern and eastern Maryland and in Virginia east of the Blue Ridge. Spring-sown oats give fairly good results in particularly favorable seasons, but the crop is not at all a reliable one. Therefore, most of the experimental work that has been done at College Park and Arlington Farm with oats has been with fall-sown varieties.

Varietal tests of winter oats have been conducted in field plats at College Park since 1908 and at Arlington Farm since 1911. Prior to 1911 this crop was grown only in the nursery at Arlington Farm. The trials at College Park during the seven years have included 13

varieties and selections, of which only 5 have been grown since 1911. At Arlington Farm 19 varieties and selections have been included, of which 14 are still grown.

The varietal tests of winter oats at College Park have been sown on the following dates: October 16, 1907; October 9, 1908; September 29, 1909; October 9, 1910; September 20, 1911; October 1, 1912; and October 4, 1913. At Arlington Farm the dates were September 23, 1910; September 8, 1911; September 11 and 14, 1912; and September 29 and 30, 1913. The average date of seeding at College Park has been a little more than 2 weeks later than at Arlington Farm. Experience has shown that in most years the date of seeding at Arlington Farm has been too early for the best results. It is believed that if the seeding of winter oats is delayed until late September or early October in this locality, more satisfactory yields usually will be obtained. At higher altitudes than Washington, D. C., earlier seeding is advisable.

The rate of seeding at College Park was 10 pecks in 1908, 1910, 1911, and 1912; 10½ pecks in 1909; and 8 pecks in 1913 and 1914. No attention was given to size of kernel in determining the rate of seeding for the several varieties. At Arlington Farm in 1911 the Winter Turf was sown at the rate of 8 pecks, the Bicknell and Culberson at the rate of 10 pecks, and the Red Rustproof at the rate of 14 pecks. In the succeeding years the 8-peck rate was used for all varieties except the Red Rustproof, which was sown at the rate of 12 pecks. These rates have been found quite satisfactory, although it is believed that a rate of 6 pecks is ample for the Winter Turf. The kernels of this variety are small and the plants are hardier and stool more freely than those of the other varieties; hence, less seed is required.

The low yields obtained from most of the varieties and selections grown at Arlington Farm in 1912 were directly due to winterkilling, a minimum temperature of -13° F. having been recorded. Thus, the yields of that year are a fair index of the relative hardiness of the several varieties and selections.

The annual and average yields per acre, in bushels of 32 pounds each, of the varieties and selections included in these tests are presented in Table X.

The Winter Turf, C. I. No. 180, has produced the highest average yield, 51.3 bushels, in the 7-year test at College Park. The Winter Turf selection, C. I. No. 274-1, ranks second, with an average of 48.37 bushels, and the Culberson, C. I. No. 273, third, with 46.3 bushels. The Bicknell, C. I. No. 206, which has been grown only six years (1909-1914), has an average yield of 49.88 bushels for that period, as compared with 49.3 bushels for the Winter Turf, 48 bushels for the Winter Turf selection, and 46.95 bushels for the Culberson for the same period.

TABLE X.—*Annual and average yields of varieties and selections of winter oats grown at the Maryland Agricultural Experiment Station (College Park) and at Arlington Farm, Va., for the years stated.*

Group and variety.	C. I. No.	Yield per acre (bushels).							
		1908	1909	1910	1911	1912	1913	1914	Average.
COLLEGE PARK (13 VARIETIES AND SELECTIONS).									
Culberson:									
Culberson.....	273	42.37	46.75	40.90	50.35	54.37	41.16	48.20	46.30
Bicknell:									
Bicknell.....	206		65.24	38.90	53.56	47.54	44.92	49.10	49.88
Red Rustproof:									
Red Rustproof.....	518	26.23	50.51	42.50	55.30				34.91
Appler.....	339	27.00							
Turkish Rustproof:									
Turkish Rustproof.....	356	37.60	34.17		57.34	40.67			33.96
Winter Turf:									
Winter Turf.....	180	63.31	33.47	46.70	52.32	66.22	49.00	48.10	51.30
Do.....	195		45.32	43.90					44.61
Do.....	203	52.47	34.78	39.10	56.98	22.16	49.21	49.00	43.39
Do.....	274	43.12	30.79			17.76			30.56
Winter Turf selection.....	274-1	50.61	38.72	43.60	54.30	47.44	46.63	57.30	48.37
Winter Turf.....	436	44.57	49.95	46.00	56.86	23.31			44.16
Dun.....	442	50.37	37.62						44.00
Miscellaneous:									
Boswell Winter.....	480	31.94	11.49						21.72
ARLINGTON FARM (12 VARIETIES AND SELECTIONS).									
Culberson:									
Culberson.....	273				40.90	¹ 19.52	² 33.50	³ 54.60	37.14
Culberson selection.....	273-19				49.40	24.53	31.90	58.50	41.08
Do.....	273-20					15.00	28.80		21.90
Do.....	651				42.80	4.75	19.70	49.30	29.14
Do.....	511-II				48.80	21.50	42.70		37.67
Bicknell:									
Bicknell.....	206				33.10	4.75	36.60	59.10	33.39
Bicknell selection.....	206-3				38.80	10.44	49.80	57.60	39.16
Do.....	206-7				40.00	10.84	46.60	53.50	37.74
Do.....	206-10				40.00	2.81		53.00	31.94
Red Rustproof:									
Red Rustproof.....	256				52.50	5.41	49.40		35.77
Red Rustproof selection.....	518-3				63.10	5.94	43.40	61.90	43.59
Do.....	518-4				50.00	1.13			25.57
Red Rustproof.....	548				60.30	6.64	45.50		37.48
Winter Turf:									
Winter Turf selection.....	274-20				26.30	20.75	46.60	64.40	39.51
Winter Turf.....	427				36.30	18.75	40.00	67.20	40.56
Do.....	431				29.40	25.31	40.00	61.90	39.15
Do.....	435				34.10	24.69	35.90	64.10	39.70
Miscellaneous:									
Selection from Appler ⁴	259-11							81.30	
Fulghum.....	708							59.50	

¹ Average of 3 check plats.² Average of 5 check plats.³ Average of 7 check plats.⁴ Distinct from the original variety.

At Arlington Farm the highest average yield for the four years (1911-1914), 43.59 bushels, was produced by the Red Rustproof selection, C. I. No. 518-3. The Culberson selection, C. I. No. 273-19, has averaged 41.08 bushels for the same period, while the four lots of Winter Turf and the best Bicknell selection (C. I. No. 206-3) are only slightly lower in yield.

LEADING VARIETIES.

Four varieties of winter oats have been of importance at both the the Maryland station and Arlington Farm. These are the Bicknell, Culberson, Red Rustproof, and Winter Turf. Several strains or

selections of each have been grown at Arlington Farm each year except of the Red Rustproof, of which only one selection has been grown during the entire four years. At College Park only one strain of each variety except the Winter Turf has been grown continuously. Of the latter, three strains have been included. The average dates of heading and maturity, height, yields of grain and of straw, and weight per bushel of the more important varieties and selections at the Maryland station and at Arlington Farm are shown in Table XI.

TABLE XI.—*Miscellaneous data for varieties of winter oats grown at the Maryland Agricultural Experiment Station (College Park) and at Arlington Farm, Va., for the years stated.*

Group and variety.	C. I. No.	Number of years grown.	Average date—		Average height.	Average yield per acre.		Average weight per bushel.
			Headed.	Ripe.		Grain.	Straw.	
COLLEGE PARK (6 VARIETIES), 1908 TO 1914, INCLUSIVE.								
Winter Turf:					<i>Inches.</i>	<i>Bushels.</i>	<i>Pounds.</i>	<i>Pounds.</i>
Winter Turf.....	180	7	¹ May 27	¹ June 28	41	51.30	² 2,480	³ 30.4
Winter Turf selection..	274-1	7	¹ June 2	¹ do ¹	41	48.37	² 2,640	³ 30.6
Winter Turf.....	203	7	¹ June 1	¹ do ¹	39	43.39	³ 2,300	³ 33.0
Average for group.....			May 31	¹ do ¹	40.3	47.69	2,470	31.3
Bicknell:								
Bicknell.....	206	6	¹ May 19	¹ June 18	36	49.88	2,150	⁴ 32.3
Culberson:								
Culberson.....	273	7	⁴ May 22	⁴ June 20	38	46.30	² 2,380	³ 30.0
Red Rustproof:								
Red Rustproof.....	518	5	¹ May 21	¹ June 23	¹ 35	34.91	¹ 1,820	¹ 29.7
ARLINGTON FARM (11 VARIETIES AND SELECTIONS), 1911 TO 1914, INCLUSIVE.								
Red Rustproof:								
Red Rustproof selection	518-3		May 20	June 12	33	43.59	2,000	27.3
Winter Turf:								
Winter Turf.....	427		June 1	June 26	39	40.56	2,610	32.5
Do.....	435		May 30	June 24	38	39.70	2,680	33.6
Winter Turf selection..	274-20		May 31	do.....	38	39.51	2,340	29.5
Winter Turf.....	431		do.....	June 25	38	39.15	2,680	31.9
Bicknell:								
Bicknell selection.....	206-3		May 22	June 11	34	39.16	2,250	34.5
Do.....	206-7		May 24	June 13	34	37.74	1,970	34.6
Bicknell.....	206		May 22	do.....	34	33.39	2,150	35.1
Culberson:								
Culberson selection.....	273-19		May 28	June 15	34	41.08	2,330	32.0
Culberson.....	273		May 27	do.....	34	37.14	2,330	33.0
Culberson selection.....	651		May 24	June 12	34	29.14	1,970	30.7
Summary of averages for Arlington Farm:								
Red Rustproof.....			May 20	do.....	33	43.59	2,000	27.3
4 Winter Turf.....			May 31	June 25	38.3	39.73	2,580	31.9
3 Bicknell.....			May 23	June 12	34.0	36.76	2,120	34.7
3 Culberson.....			May 26	June 14	34.0	35.79	2,210	31.9

¹ Data for 3 years only. ² Data for 6 years only. ³ Data for 5 years only. ⁴ Data for 4 years only.

The data on the average date of ripening at Arlington Farm (Table XI) show that the Bicknell and Red Rustproof ripen about 2 weeks earlier and the Culberson from 10 days to 2 weeks earlier than the Winter Turf. The data for College Park show less difference among

the varieties, though the Winter Turf is several days later than any of the others. The average height of the Bicknell, Culberson, and Red Rustproof is about the same, 34 inches at Arlington Farm and 35 to 38 inches at College Park. The Winter Turf is about 4 inches taller than the other varieties at both places. The Winter Turf has produced the highest yields of straw and the Bicknell the highest weight per bushel. The Red Rustproof has been lowest both in yield of straw and in weight per bushel.

Descriptions of the more important varieties and selections are given in the following paragraphs. Heads of these varieties are shown in figure 5.



FIG. 5.—Heads of four varieties of winter oats grown at the Maryland Agricultural Experiment Station and at Arlington Farm: 1, Culberson; 2, Bicknell; 3, Winter Turf; 4, Red Rustproof.

Bicknell.—The Bicknell oat, C. I. No. 206, was obtained from Argentina by the United States Department of Agriculture in 1902, through Mr. F. W. Bicknell. The panicles are small and rather dense. The short, buff kernels are usually very plump, so that the weight per bushel is high. This variety is one of the earliest to mature, usually ripening about June 12 to 15. The Bicknell has yielded slightly more than any other variety for the six years it has been grown at College Park, where it has produced quite consistently high yields every year. At Arlington Farm the original variety has averaged 10.2 bushels less and the best selection 4.43 bushels less in a 4-year test than the highest yielding variety in the test, which was a Red

Rustproof selection. The Bicknell was injured more than either the Winter Turf or Culberson by the severe cold in January, 1912. There is little difference in the appearance of the original variety and of the pure-line selections from it which have been grown at Arlington Farm, but in a 4-year test C. I. No. 206-3 has averaged 5.77 bushels and C. I. No. 206-7 4.35 bushels to the acre more than the unselected stock of C. I. No. 206.

Culberson.—The Culberson oat is supposed to have originated as a mass selection from the Red Rustproof, as commercial stocks of that variety usually contain mixtures similar to the Culberson. It grows taller than the Red Rustproof and has larger, more spreading panicles and much smaller kernels. The kernels are decidedly variable in color, ranging from white through brown to grayish black. The strains which bear brown or black kernels do not differ otherwise in appearance from the white-kerneled strains. In commercial stocks of the Culberson at least 90 per cent of the kernels are usually white. The Culberson matures 2 or 3 days later than the Bicknell and Red Rustproof and about 10 days earlier than Winter Turf.

Only the original stock of the Culberson, C. I. No. 273, has been included in the tests at College Park. This variety has been very consistent in yield, ranging from 40.9 to 54.37 bushels during the seven years, with an average of 46.3 bushels. This average yield is lower than that of the Winter Turf and is also lower than that of the Bicknell for the six years during which that variety has been grown. The yield of the Culberson was considerably higher than that of the Red Rustproof for the five years from 1908 to 1912. At Arlington Farm the original stock of the Culberson has produced an average yield of 37.14 bushels in the four years from 1911 to 1914. The average yield of the Culberson at Arlington Farm was from 2 to 3 bushels lower than that of the various strains of the Winter Turf, about $6\frac{1}{2}$ bushels lower than the best Red Rustproof, and 2 bushels lower than the best selection from the Bicknell. The average weight per bushel of the Culberson at Arlington Farm for the four years was 33 pounds, which is higher than that of any other variety except the Bicknell.

Two selections from the Culberson, C. I. No. 273, have been grown for four years at Arlington Farm. These are C. I. Nos. 273-19 and 651. The former is a pure line with brown kernels, which otherwise is not distinguishable in appearance from the original stock. It has exceeded the unselected variety in average yield by nearly 4 bushels. C. I. No. 651 is a selection (No. 5) which was made in 1908 by Prof. C. A. Mooers at the Tennessee Agricultural Experiment Station. It matures about three days earlier than the original Culberson, produces less straw, and has brownish black kernels. It is apparently less hardy than the original stock, as it winterkilled much more in the

severe winter of 1911-12. The average yield for the four years is 8 bushels less than that of C. I. No. 273.

From the records at Arlington Farm and College Park in 1912, the Culberson appears to rank next in hardiness to the Winter Turf. It matures early, produces good yields of grain and straw, and because of its hardiness is apparently one of the best varieties for growing in this locality. This variety makes a heavier growth of straw and leaves than the Bicknell or Red Rustproof and is to be preferred to those varieties for the production of hay.

Red Rustproof.—The Red Rustproof is supposed to have been developed from *Avena sterilis*, a species of wild oat which is native to the countries surrounding the Mediterranean Sea. This variety has been grown for many years in the southern United States. Its origin is not definitely known, though probably it was imported from southern Europe. Numerous names have been applied to the Red Rustproof and selections from it. These names include Texas Red Rustproof, Texas Red, Appler, Bancroft, Cook, Hundred Bushel, and Lawson. Some of the selections probably are superior to the original variety.

The Red Rustproof has stiff, rather short straw, with small, short, branched heads. The kernels are large, are almost always awned, and usually bear basal bristles. The second kernel in the spikelet, which is only slightly smaller than the first, usually bears a weak awn. The awns, basal bristles, and the long points of the lemmas prevent the kernels from packing closely and hence cause the weight per bushel of this variety to be low. They also make it difficult to sow with the grain drill, as the seed does not feed freely. The average weight per bushel at Arlington Farm was 27.3 pounds, as compared with 33 pounds for the Culberson and 33.6 pounds for the best strains of the Winter Turf in the same years. The Red Rustproof ripens at about the same time as the Bicknell and two or three days earlier than the Culberson.

The Red Rustproof is the oat which is most commonly grown from both fall and spring seeding in the Southern States. In the vicinity of Washington, D. C., it is near its northern limit of winter hardiness, as was shown by the low yield produced at Arlington Farm in 1912 and the total failure at College Park that year. In favorable or even in ordinary years the Red Rustproof produces yields as good as or better than those of the Culberson and Winter Turf. In severe winters this variety may be expected to winterkill almost completely.

At College Park the only lot of Red Rustproof which was grown more than one year was C. I. No. 518. This strain produced a low yield in 1908, good yields in 1909, 1910, and 1911, and was a total failure in 1912. It was not grown in 1913 and 1914. At Arlington Farm two unselected lots of the Red Rustproof, C. I. Nos. 256 and 548,

were grown from 1911 to 1913. During these years they produced slightly larger yields than any other varieties included in the tests except the Red Rustproof selection, C. I. No. 518-3. Like most commercial stocks of the Red Rustproof, they contained a considerable mixture of other varieties and hence were discarded after the 1913 crop was harvested. A pure-line selection from the Red Rustproof, C. I. No. 518-3, has been grown from 1911 to 1914, with an average yield of 43.59 bushels to the acre. This average yield is $2\frac{1}{2}$ bushels higher than that of the best Culberson selection and 3 bushels higher than that of the best Winter Turf.

Winter Turf.—The panicles of the Winter Turf oat are medium to large, containing about the same number of kernels as those of the Culberson. The kernels are small to medium in size and grayish white or brownish white in color. The veins on the flowering glumes are distinctly darker than the ground color of the glume, giving a striped appearance to the kernel. In favorable seasons the kernels are plump and the weight per bushel is high. The variety is late in maturing, usually ripening about the end of June in the locality of Washington.

The Winter Turf is commonly grown from fall seeding or from very early spring seeding in the northern half of the Southern States. It does not yield well in the Gulf States. This variety is variously known as Winter Turf, Grazing, Gray Winter, Virginia Winter, Dewey, Snoma, etc. It is the hardiest of all the winter oats, having produced nearly as good yields after the severe winter of 1912 as in ordinary years. This variety is extensively grown for grazing; hence one of the names. Its fall growth is distinctly turflike, somewhat resembling that of winter rye. The Winter Turf stools more freely than other varieties of winter oats and produces a taller and more slender straw. For these reasons it is quite likely to lodge, and this tendency is further increased by its late maturity and consequent exposure to a greater number of storms than the early varieties.

Three lots of the Winter Turf, C. I. Nos. 180, 203, and 274-1, the last a pure-line selection, have been grown for seven years at College Park. Four other strains have been grown from two to five years. C. I. No. 180 produced an average yield of 51.3 bushels in seven years, which is the highest yield recorded at College Park. The next highest yield is 48.37 bushels from the pure-line selection C. I. No. 274-20. At Arlington Farm C. I. Nos. 427, 431, and 435 and the pure-line selection C. I. No. 274-20 have been grown for the four years from 1911 to 1914. These strains have differed little in yield, C. I. No. 427 having produced the highest and C. I. No. 431 the lowest yield, 40.56 and 39.15 bushels, respectively. The Winter Turf varieties have averaged from 3 to $4\frac{1}{2}$ bushels less than the best Red Rustproof selection and from one-half bushel to 2 bushels less than the best Culberson selection.

The Winter Turf, because of its hardness, is the most dependable variety for the vicinity of Washington, D. C. Its late maturity and its tendency to lodge, however, make it rather less desirable than the Culberson, Bicknell, and Red Rustproof. It matures at about the same time as wheat, while the other varieties may be harvested before the wheat crop is ripe. Where winter wheat is grown on the same farm, the earlier varieties are to be preferred. As they are less handy, they must be sown earlier than is necessary for the Winter Turf.

EXPERIMENTS WITH WINTER BARLEY.

Varietal tests of winter barley have been conducted at College Park since 1907 and at Arlington Farm since 1908. The tests at the former place have included 12 varieties, of which only four have been continued for the entire seven years (1908 to 1914). At Arlington Farm 56 varieties and strains have been grown from one to six years, most of them for short periods only.

The dates of seeding at College Park during the past seven years were as follows: October 17, 1907; October 9, 1908; September 29, 1909; September 21, 1910; September 20, 1911; October 1, 1912; and October 4, 1913, the average date being about October 2. The dates of seeding at Arlington Farm were September 29, 1908; September 21, 1909; September 15, 1910; September 10, 1911; September 16, 1912; and October 6, 1913, the average being about September 21, or 11 days earlier than for College Park. Experience has shown that the date of seeding this crop at Arlington Farm has been too early in most years for the best results. On the other hand, the crop occasionally has been sown too late at College Park. While no definite rule can be formulated, it is believed that sowing between September 25 and October 5 will give the best results under average conditions.

TABLE XII.—*Annual and average yields of varieties of winter barley grown at the Maryland Agricultural Experiment Station (College Park) and at Arlington Farm, Va., for the years stated.*

Group and variety.	C. I. No.	Yield per acre (bushels).							
		1908	1909	1910	1911	1912	1913	1914	Average.
COLLEGE PARK (12 VARIETIES).									
Six-rowed hulled:									
Maryland Winter.....	518	32.85	36.72	24.70	31.87	42.03	32.13	37.50	33.97
Mammoth Winter.....	410	23.53	34.71	20.10	32.96	47.38	35.17	39.60	33.35
Tennessee Winter.....	257	39.79	29.84	20.70	32.79	42.58	31.83	35.80	33.33
Winter 6-rowed.....	328	24.73	27.58	22.80	36.36	33.91	24.92	35.40	29.39
Arlington (Arlington Awnless).....	702						16.42	17.60	17.01
Squarehead Winter.....	252	29.72	35.20						32.46
Tenarab.....	662	24.07	30.41						27.24
Dutrow Winter ¹			32.80	22.60					27.70
Han River.....	206	28.51							
Black Winter.....	337	25.39							
Albacete.....	199	21.62							
Greece.....	221	17.77							

¹ A variety commonly grown in Frederick County, Md.

TABLE XII.—*Annual and average yields of varieties of winter barley grown at the Maryland Agricultural Experiment Station (College Park) and at Arlington Farm, Va., for the years stated—Continued.*

Group and variety.	C. I. No.	Yield per acre (bushels).							Average.
		1908	1909	1910	1911	1912	1913	1914	
ARLINGTON FARM (56 VARIETIES AND STRAINS).									
Six-rowed hulled:									
Tennessee Winter	257		41.70	23.40	15.00	35.33	¹ 21.70	² 30.70	27.97
Wisconsin Winter	519		45.00	14.27	15.40	25.52	31.40	53.50	27.52
Maryland Winter	518		39.70	³ 27.31	(⁴)	(⁴)	21.50	24.20	28.10
Texas Winter	554			28.64	22.80	26.25	22.50	22.80	24.60
Virginia (Virginia Hooded) ⁵	648			45.81	13.40	0	28.40	19.40	21.40
Large-grained Winter	408			21.25	(⁴)	(⁴)	30.40	31.30	27.65
Hybrid ⁶	896				17.30	38.04	28.10	26.30	27.44
Do. ⁶	895				18.90	30.47	28.80	29.20	26.84
Canada Winter	713				16.00	29.29	25.00	28.50	24.70
Tenkau ⁷	646				13.30		39.60	32.10	28.33
Squarehead Winter	252					24.17	30.80	27.70	27.56
Tanbush	578						27.90	25.80	26.85
Argentine	223				(⁴)	18.23	16.70	33.30	22.74
Arlington (Arlington Awnless) ⁸	702					20.52	17.50	22.30	20.11
Scottish Pearl	277						36.00	32.30	34.15
Mammoth Winter	220			(⁴)	(⁴)			23.50	
Odessa	182			17.50	(⁴)		28.50		23.00
Telli	194			22.50	(⁴)	(⁴)	31.50		27.00
Gatami	575			16.46	15.20	0			15.83
Albacete	199			15.41	12.30		24.20		17.30
Bestehorn Giant	414			19.60	(⁴)	51.42	10.00		27.01
Turkestan	712				3.30	2.79	4.20		3.43
Manchuria	613			25.20	16.00				20.60
Caveda	455					23.58	9.20		16.39
Han River	206				(⁴)	2.92			
Greece	221			34.06	(⁴)				
Alaska	534				(⁴)		27.50		
Blue Ribbon	611				(⁴)		26.00		
Union Winter	583							27.09	
Hybrid ⁷	901							32.50	
Do. ⁷	902							24.80	
Two-rowed hulled:									
Svanhals	187			20.83	8.30	15.67	25.30	25.80	19.18
Nesbian ⁶	647				15.90	12.33	24.00	24.80	19.26
Omar ⁶	898						25.00	25.60	25.30
Hanna	287			26.66	14.80	11.83	18.80		18.02
Pedigree Chevalier	156			14.58	36.90	7.17	14.60		18.31
Black Arabian	202				11.70	37.92	18.50		22.71
Hanna	203				6.30	6.25	18.10		10.22
Princess	529			23.33	8.30	0			10.54
White Smyrna	195					36.67	8.80		22.74
Hannchen	531				40.80	0			20.40
Bavarian	160				30.00	0			15.00
Do	159				41.00	0			20.50
Princess	193			14.79	27.10	0			13.96
Chevalier II	200				5.40	0			2.70
Prize Prolific	169				9.20	0			4.60
Chevalier	612			15.00	19.20				17.10
Black Smyrna	191				13.10		28.30		20.70
Orel	351				13.40	0			17.70
White Smyrna	530					31.88	22.00		26.94
Naked: ⁸									
Hanse ⁷	703				24.00	20.58	11.30	27.30	20.80
Sangatsuka	78				21.30	7.83	19.00		16.04
Hankau	197				20.50	7.63			14.07
Black Hull-less	618				13.70	0			6.85
Kamamugi	577				17.00				
Wakamatsu	579				13.70				

¹ Average yield of 7 check plats.² Average yield of 9 check plats.³ Average yield of 6 check plats.⁴ Yields not comparable, due to pronounced soil variation.⁵ Selection from the cross, Tennessee Winter (C. I. No. 257), a 6-rowed bearded hulled winter barley, × Success (C. I. No. 507), a 6-rowed hooded hulled spring barley.⁶ Selection from the cross, Tennessee Winter (C. I. No. 257) × Black Arabian (C. I. No. 202), a 2-rowed bearded hulled spring barley.⁷ Selection from the cross, Tennessee Winter (C. I. No. 257) × Hankau (C. I. No. 197), a 6-rowed bearded naked spring barley.⁸ The yields of these varieties were calculated at 60 pounds per bushel. All are 6-rowed awned varieties.

The rate of seeding at College Park has been 8 pecks for all years except 1909 and 1911, when the rates were $10\frac{1}{2}$ and 11 pecks, respectively. At Arlington Farm the hulled varieties have been sown uniformly at the rate of 8 pecks, which appears to be about the best rate. The naked barleys have been sown at the rate of 6 pecks in all years except 1911, when 8 pecks were sown.

The annual and average yields per acre of the varieties tested at College Park during the seven years from 1908 to 1914, inclusive, and



FIG. 6.—Heads of three varieties of winter barley grown at Arlington Farm: 1, Tennessee Winter; 2, Wisconsin Winter; 3, Omar.

at Arlington Farm during the six years from 1909 to 1914, inclusive, are shown in Table XII.

All the varieties included in the tests at College Park, as shown in Table XII, belong to the 6-rowed hulled group, all except the Arlington being quite similar to the Tennessee Winter (fig. 6) and Maryland Winter varieties (C. I. Nos. 257 and 518, respectively). Of the 56 varieties and strains included in the tests at Arlington Farm (Table XII), 31 belong to the 6-rowed hulled group, 19 to the 2-rowed hulled, and 6 to the naked or hull-less group. Most of these varieties are bearded.

The varieties of the 6-rowed hulled group usually have produced the best yields. All the 2-rowed barleys with the exception of the

two hybrids, Nesbian and Omar, are spring varieties that have been grown from fall seeding. In 1911 several of these 2-rowed spring barleys outyielded the best 6-rowed winter barleys, but the following year more than half of them were completely winterkilled during the severe weather in January. It is doubtful whether any of the 2-rowed spring varieties can be grown successfully from fall seeding during a series of years.

The yields obtained from the naked barleys also are unsatisfactory. The yields of these varieties shown in Table XII are calculated at 60 pounds to the bushel, the standard weight for this group.

The average dates of heading and of maturity, height, yield of grain and of straw, and weight per bushel of the four leading varieties of barley at College Park for the seven years from 1908 to 1914 are shown in Table XIII. The same data for 16 of the more important varieties and strains grown at Arlington Farm for periods ranging from two to six years are also given.

TABLE XIII.—*Miscellaneous data for varieties of winter barley grown at the Maryland Agricultural Experiment Station (College Park) and at Arlington Farm, Va., for the years stated.*

Variety.	C. I. No.	Number of years grown.	Average date—		Average height.	Average yield per acre.		Average weight per bushel.
			Headed. ¹	Ripe. ¹		Grain.	Straw. ²	
COLLEGE PARK (4 LEADING VARIETIES), 1908 TO 1914, INCLUSIVE.								
Maryland Winter.....	518	7	May 8	June 10	<i>Inches.</i> 34	<i>Bush.</i> 33.97	<i>Lbs.</i> 2,050	<i>Lbs.</i> ³ 40.4
Mammoth Winter.....	410	7	do.....	do.....	34	33.35	2,200	⁴ 43.0
Tennessee Winter.....	257	7	do.....	do.....	33	33.33	2,140	1 39.7
Winter 6-rowed.....	328	7	May 11	June 12	34	29.39	1,880	⁴ 42.5
ARLINGTON FARM (16 VARIETIES AND STRAINS), 1909 TO 1914, INCLUSIVE.								
Six-rowed hulled:								
Tennessee Winter.....	257	6	May 6	June 3	² 33	27.97	² 2,230	43.3
Wisconsin Winter.....	519	6	May 8	June 6	² 34	27.52	² 2,540	43.6
Maryland Winter.....	518	6	May 7	June 3	30	³ 28.10	⁵ 2,050	43.8
Texas Winter.....	554	5	do.....	June 4	30	24.60	⁵ 2,050	44.7
Virginia (Virginia Hooded).....	648	5	Apr. 26	May 30	34	21.40	⁵ 1,970	³ 38.8
Large-grained Winter.....	408	4	May 17	June 14	34	⁴ 27.65	⁶ 3,230	45.6
Hybrid.....	896	4	May 9	June 2	34	27.44	2,030	41.6
Do.....	895	4	May 10	do.....	33	26.84	1,800	40.5
Canada Winter.....	713	4	do.....	June 3	35	24.70	1,980	42.5
Tenkau.....	646	3	do.....	June 4	35	28.33	2,650	43.3
Squarehead Winter.....	252	3	May 11	June 6	30	27.56	2,570	44.0
Arlington (Arlington Awnless).....	702	3	Apr. 26	May 26	37	20.11	1,330	49.3
Two-rowed hulled:								
Svanhals.....	187	5	May 6	June 5	33	19.18	³ 1,840	48.1
Nesbian.....	647	4	May 8	June 4	33	19.26	⁴ 2,260	47.8
Omar.....	898	2	May 11	June 6	37	25.30	2,690	47.5
Naked:								
Hansee.....	703	4	May 1	May 31	33.	20.80	2,570	60.5

¹ Data for 6 years only.

² Data for 5 years only.

³ Data for 4 years only.

⁴ Data for 3 years only.

⁵ Data for 2 years only.

⁶ Data for 1 year only.

Table XIII shows that the more important varieties have ripened about June 10 at College Park and from June 3 to 6 at Arlington Farm. The earliest varieties at Arlington Farm are the three hybrids, Arling-

ton, Virginia, and Hansee. At College Park the varieties have averaged about 34 inches in height. At Arlington Farm the range has been from 30 to 37 inches, with the more important varieties averaging about 34 inches. The yields of straw have averaged about 1 ton to the acre, or rather less than was obtained from oats during the same years. The weight per measured bushel of nearly all varieties is considerably below the standard weight at both College Park and Arlington Farm. The Arlington is the only 6-rowed hulled variety which has averaged more than 48 pounds to the bushel. The 2-rowed varieties averaged almost exactly the standard weight per bushel.

LEADING VARIETIES.

The leading varieties of barley at College Park and Arlington Farm all belong to the 6-rowed bearded hulled group. Two varieties of the 2-rowed bearded hulled group and one of the naked group, however, are of some interest. Brief descriptions of the more important varieties are included in the paragraphs which follow.

THE 6-ROWED HULLED GROUP.

The greater part of the varieties in the 6-rowed hulled group which have been tested at College Park and Arlington Farm are true winter forms. About one-fourth of the varieties which have been grown at Arlington Farm, however, are really spring forms which have been sown in the fall. For the most part these varieties are fairly winter hardy, but they still retain the erect early growth and other characteristics of the spring forms. The most important 6-rowed winter barley is the Tennessee Winter. Other varieties of special interest are the Wisconsin Winter, the Arlington, and the Virginia.

Tennessee Winter.—A 6-rowed bearded hulled winter barley has been grown for many years in the South Atlantic and Gulf States. This variety was improved by mass selection at the Tennessee Agricultural Experiment Station. It was first distributed from that station about 1900, when it was given the name "Tennessee Winter." At College Park the Tennessee Winter, C. I. No. 257, produced an average yield of 33.33 bushels during the seven years from 1908 to 1914. This is slightly less than has been produced by the very similar variety, Maryland Winter, C. I. No. 518. At Arlington Farm the Tennessee Winter has produced an average yield of 27.97 bushels in the six years from 1909 to 1914. Only one other variety, the Wisconsin Winter, C. I. No. 519, has been grown on comparable land during the entire six years. The yield of Wisconsin Winter was 0.45 bushel less than that of Tennessee Winter.

The average date of maturity of the Tennessee Winter at Arlington Farm is June 3 and at College Park June 10. The average height of the plants was 33 inches. The average yield of straw was slightly

more than 1 ton. The average weight per bushel of the variety for six years at Arlington Farm was 43.3 pounds.

Numerous other varieties which have been included in the tests are practically identical with the Tennessee Winter in appearance, hardiness, and yield. Among these are the Maryland Winter, C. I. No. 518; Texas Winter, C. I. No. 554; Union Winter, C. I. No. 583; and Canada Winter, C. I. No. 713. Two selections from the cross between the Tennessee Winter and the Black Arabian, C. I. Nos. 895 and 896, are also much like the Tennessee Winter. They have been among the best yielders during the four years they have been grown. The Tennessee Winter and similar varieties seem to be better adapted for fall seeding in the locality of Washington, D. C., than any of the other winter barleys.

Wisconsin Winter.—The Wisconsin Winter barley, C. I. No. 519, appears to be a winter variety from a region of mild winters. It is winter hardy in the vicinity of Washington, but the plants make a more vigorous top growth in the fall than those of the Tennessee Winter and similar varieties, while the leaves are much wider and the winter habit is less pronounced. The yield of the Wisconsin Winter at Arlington Farm during the six years from 1909 to 1914 was 27.52 bushels, which is 0.45 bushel less than that of the Tennessee Winter for the same period. The average date of maturity for the variety is three days later than that of the Tennessee Winter.

Arlington.—The Arlington (Arlington Awnless) barley, C. I. No. 702, is a 6-rowed awnless hulled barley which was developed by selection from a hybrid between the Tennessee Winter and the Black Arabian, the latter being a 2-rowed bearded hulled variety. This selection was continued through several years by Mr. H. B. Derr, formerly of the Office of Cereal Investigations.¹ It is the earliest variety included in the tests, ripening about May 26. Because of its awnless character and its earliness it was expected that the Arlington would become a very important winter variety, as it appeared to be nearly as hardy as the Tennessee Winter. The data on yield contained in Table XII, however, show that the Arlington is much inferior to the Tennessee Winter and similar varieties. In the three years from 1912 to 1914 at Arlington Farm the Arlington averaged 20.11 and the Tennessee Winter 29.24 bushels. The heads of the Arlington are very brittle, so that a considerable part of the grain is lost by shattering in harvesting and subsequent handling before thrashing. For these reasons it is doubtful whether the Arlington will become of much importance.

Virginia.—The name Virginia (Virginia Hooded), C. I. No. 648, was applied by Mr. H. B. Derr to a hooded selection from a hybrid between the Tennessee Winter and the Success, a 6-rowed hooded hulled spring barley. It was hoped that this variety would prove to

¹ Derr, H. B. A new awnless barley. *In Science*, n. s., v. 32, no. 823, p. 473-474, 1 fig., 1910.

be winter hardy and that it would be a valuable addition to the list of winter barleys, as its freedom from beards makes it much more pleasant to handle than the ordinary winter varieties. It entirely winterkilled, however, in January, 1912, and was rather badly injured in one or two other years. Its average yield for the five years from 1910 to 1914 at Arlington Farm is 21.4 bushels, which is about 3 bushels less than that of the Tennessee Winter, Texas Winter, and similar varieties for the same period. This variety matures about four days earlier than the Tennessee Winter. The yield of straw is rather less than from the bearded winter varieties. The grain has been light and chaffy, averaging only 38.8 pounds to the bushel, as compared with 43.3 pounds for the Tennessee Winter.

THE 2-ROWED HULLED GROUP.

Most varieties of the 2-rowed group which have been grown at Arlington Farm were originally spring barleys which have been sown in the fall. They have not proved to be winter hardy in years when low temperatures are recorded, though in favorable years they have produced very high yields. They are not sufficiently dependable to make them worthy of recommendation.

Two selections from a hybrid between the Tennessee Winter and the Black Arabian, however, appear to be quite hardy and worthy of further test. These are the Nesbian, C. I. No. 647, and the Omar, C. I. No. 898. It is probable that the latter is the better of the two selections, though it has not been tested long enough to determine its value fully. These hybrids mature a day or two later than the Tennessee Winter. In the tests so far conducted they have not been high in yield. The average yield of the Omar for the two years in which it has been tested is 25.3 bushels, as compared with 26.2 bushels for the Tennessee Winter and 32.45 bushels for the Wisconsin Winter in the same years. The quality of the grain produced by these 2-rowed varieties is much better than that of the 6-rowed barleys, the average weight per bushel being practically 48 pounds.

THE NAKED GROUP.

None of the varieties in the naked group have produced yields nearly as high as those of the 6-rowed hulled varieties. The best naked barley which has been included in the test is a selection from a hybrid which has been called Hansee, C. I. No. 703. This selection was made by Mr. H. B. Derr from a cross between the Tennessee Winter and the Hankau, C. I. No. 197, the latter a 6-rowed bearded naked variety. The Hansee is also a 6-rowed bearded barley. While it is apparently not a true winter variety, it is much more hardy than any of the other naked barleys which have been tested. Its average yield for the four years it has been grown at Arlington Farm is 20.8

bushels of 60 pounds each. This is equivalent to about 26 bushels of hulled barley. The Hansee matures about three days earlier than the Tennessee Winter.

EXPERIMENTS WITH SPRING-SOWN GRAINS.

Several attempts have been made to grow spring wheat, oats, and barley at Arlington Farm, but with little or no success. Of the three, the best yields have been obtained from spring oats. The yields, however, were much lower than from fall-sown oats, and the crop is much more uncertain. No profitable yields of spring barley and spring wheat have been produced in these experiments. Each time that spring wheat has been grown rust has practically destroyed the crop.

A few varieties of buckwheat have been tested, but with very unsatisfactory results. This crop is not well adapted to the warmer portions of the humid area. The highest yield obtained with buckwheat at Arlington Farm was about 10 bushels per acre.

The prosos (broom-corn millets) also have been tested as a grain crop, but without success. Of 10 varieties grown at Arlington Farm in 1911 and 1912, not one produced anything approaching a satisfactory yield. Proso is not of value as a grain crop in the humid portions of the United States.

The few tests which have been made of grain sorghum indicate that this crop does fairly well at Arlington Farm. However, it is not a profitable crop where corn can be grown successfully, and there is no reason to grow any of the various forms in this locality.

SUMMARY.

Experiments with cereals have been conducted since 1907 at College Park, Md. (in cooperation with the Maryland Agricultural Experiment Station), and at Arlington Farm, Va. The results of varietal tests of the different winter cereals are reported in this bulletin.

The average annual rainfall for the ten 12-month periods from July 1, 1904, to June 30, 1914, inclusive, at Washington, D. C., was 42.33 inches. The average annual rainfall at College Park is about 4 inches less than at Washington.

The size of the plats on which the varietal tests were conducted was in most cases one-twentieth of an acre.

The varietal tests at College Park have included 107 varieties and races of wheat, 5 of spelt, 3 of emmer, 13 of oats, and 12 of barley. At Arlington Farm the tests have included 43 varieties and races of winter wheat, 12 of rye, 4 of spelt, 2 of emmer, 19 of oats, and 56 of barley. Only winter varieties of the various cereals are adapted.

Of the 43 winter wheats tested at Arlington Farm, 11 are selections from hybrids which have been developed at College Park and Arlington Farm. The most promising of these hybrids is the Virginia, C. I. No. 3277.

The five leading varieties of wheat at College Park, with the 7-year average yield of each in bushels per acre, are as follows: China, 31.17 bushels; Mammoth Red, 31.09 bushels; Bearded Purple Straw, 30.95 bushels; Turkish Amber, 30.11 bushels; and Lancaster, 30.03 bushels.

The five leading varieties of winter wheat at Arlington Farm, with the 5-year average yield of each in bushels per acre, are as follows: Purple Straw (C. I. No. 1915), 32.09 bushels; Lancaster, 29.74 bushels; Dawson Golden Chaff, 29.37 bushels; Fultz, 29.17 bushels; and Purple Straw (C. I. No. 1957), 29.17 bushels.

A rate-of-seeding test with several varieties of winter wheat at Arlington Farm indicates that better yields may be obtained on well-prepared land from sowing 3 or 4 pecks than from heavier rates of seeding.

Several varieties of winter spelt and one of emmer have been tested. The best variety of winter spelt, the Alstrom, has a 6-year average yield at College Park of 63.23 bushels and a 5-year average yield at Arlington Farm of 74.08 bushels. The Black Winter emmer has averaged 36.57 and 22.33 bushels, respectively, for the same periods at College Park and Arlington Farm.

A varietal test of rye has been conducted at Arlington Farm only. Of the 12 varieties and selections tested, the Giant Winter, Virginia Winter, and Abruzzes are the leading varieties. The average yield of Giant Winter rye in a 4-year test was 32.89 bushels. Earlier seeding than is commonly practiced by the average farmer has given very satisfactory results with this crop.

The leading varieties of winter oats at College Park are the Winter Turf, Bicknell, and Culberson, in the order named. The most promising at Arlington Farm are the Red Rustproof, Winter Turf, Bicknell, and Culberson.

The Winter Turf is the hardiest and most dependable variety, but its late maturity and tendency to lodge are objectionable. The Culberson and Bicknell mature ten days to two weeks earlier than the Winter Turf and are to be preferred to it in eastern and southern Maryland and eastern Virginia.

The leading varieties of winter barley at College Park are the Maryland Winter, Mammoth Winter, and Tennessee Winter. These varieties are practically identical. Of the varieties tested at Arlington the Tennessee Winter, Wisconsin Winter, Maryland Winter, and Texas Winter yielded best.

None of the eighteen 2-rowed spring barleys that have been grown from fall seeding at Arlington Farm have been satisfactory. A hybrid

2-rowed winter barley has been developed, which produced an average yield of 25.30 bushels in 1913 and 1914. None of the naked barleys has given satisfactory yields.

Satisfactory results have not been obtained with spring-sown grains at Arlington. None is reliable enough to be recommended.

Winter wheat, spelt, rye, barley, and oats have all given very satisfactory yields. The feed grains, oats, barley, and spelt, should be more generally grown. The varieties most strongly recommended for eastern and southern Maryland and eastern Virginia are as follows:

Winter wheat:	Winter spelt:	Winter oats—Continued.
China.	Alstroum.	Culberson.
Fulcaster.	Winter rye:	Bicknell.
Dietz.	Giant Winter.	Red Rustproof.
Fultz.	Virginia Winter.	Winter barley:
Purple Straw.	Abruzzes.	Tennessee Winter.
Bearded Winter Fife.	Winter oats:	Wisconsin Winter.
Bearded Purple Straw.	Winter Turf.	

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UNITED STATES DEPARTMENT OF AGRICULTURE



BULLETIN No. 337



OFFICE OF THE SECRETARY
Contribution from the Office of Farm Management
W. L. Spillman, Chief

Washington, D. C.

PROFESSIONAL PAPER

January 13, 1916

A STUDY OF THE TENANT SYSTEMS OF FARMING IN THE YAZOO-MISSISSIPPI DELTA.

By E. A. BOEGER, *Agriculturist*, and E. A. GOLDENWEISER, *Statistician*,
Office of Farm Management.

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SUMMARY OF RESULTS.

This study, made in 1913, is based on 878 records relating to the business of tenants on plantations in the Yazoo-Mississippi Delta. Comparison is made between share croppers, who supply nothing but their labor and receive one-half of the crop; share renters, who supply their own implements and live stock and receive two-thirds or three-fourths of the crop; and cash renters, who supply the same items as share renters but pay a fixed rent in cash or lint cotton.

The principal facts brought out by this investigation may be stated as follows:

The share cropping system is the safest for the tenant. The share cropper is practically assured of average wages for his work, but he rarely makes a large income.

The share renter fails more frequently to make even a bare living, but has a better chance to make a good income than has the share cropper.

The cash renter runs still greater risk of failure, but has the greatest opportunity of making a labor income of not less than \$1,000.

The average labor income for share croppers was \$333; for share renters, \$398; and for cash renters, \$478.

From the point of view of the landlord the situation is reversed.

He is assured of a return of between 6 and 7 per cent on his investment where the land is operated by cash renters, no matter what the yield or the tenant's labor income may be.

Where the land is worked by share croppers or share renters the landlord's rate of interest often falls below 6 per cent, but when the yield is good and the tenant makes a good return, the rate of interest sometimes rises to more than three times that amount.

It appears that the landlord can make better money, on the average, when he rents his land on some system of shares. The average rate of interest received by the landlord from share croppers was 13.6 per cent; from share renters, 11.8 per cent; and from cash renters, 6.6 per cent.

The holdings of share croppers are considerably smaller, on the average, than those of share renters or of cash renters, and there are few share croppers having as much as 25 acres in cotton, while about one-third of the share renters and of the cash renters have at least that acreage. The labor income of tenants increases directly with the increase in cotton acreage, but the rate of interest on the landlord's investment appears to be but little affected by the size of the holdings.

The principal factor in determining the amount of the tenant's labor income and the rate of the landlord's profits in this region is the yield of cotton per acre. The relationship between yield of cotton and labor income, however, is much closer on cash renters' farms than on those of share croppers, while the effect of yield on the landlord's profits is more apparent under the share cropping than under the share renting or the cash renting system. The tenant's incentive for securing a good crop is consequently greater among those who rent for cash, but, on the other hand, the landlord is more directly interested in the magnitude of the yield per acre on the land of his share croppers.

TERRITORY STUDIED.

The agriculture of the Yazoo-Mississippi Delta¹ is conducted largely on the plantation system. Under this system white owners let their holdings in small tracts among negro tenants, and are very largely guided in determining the number of acres assigned to each tenant, and in deciding on the terms of the contract, by the known character of the tenant, his reliability and his industry, and the size of his family.

The problems of farm tenure in the Delta are not unlike those prevailing in other portions of the cotton belt, but are decidedly

¹ The Yazoo-Mississippi Delta includes the following nine counties in Mississippi: Bolivar, Coahoma, Issaquena, Leflore, Quitman, Sharkey, Sunflower, Tunica, and Washington, and adjoining parts of Holmes, Tallahatchie, Warren, and Yazoo Counties.

different from those prevailing in other sections of the United States. Broadly speaking, it may be said that the different methods of tenure in this region represent the various attempts on the part of planters to secure a satisfactory supply of labor to grow their cotton, and on the part of tenants to secure the best return for their ability to produce that crop.

This region, which comprises about 6,400 square miles, is bounded on the west by the Mississippi River and on the east by a line of bluffs, and extends from just below Memphis on the north to Vicksburg on the south. Prior to the erection of the levees the Delta was frequently subject to inundations. The soil of the region is as fertile as is to be found anywhere on the continent. The value of farm land per acre is between \$25 and \$50 in these counties, according to the census of 1910, as compared with an average of \$14 for the entire State. This fertile soil, together with a suitable climate, makes the Delta an excellent cotton region, and, in 1909, 76 per cent of the crop land in the nine counties was devoted to this crop, 21.2 per cent being in corn and only 2.8 per cent in all other crops.

The problem of tenancy is especially important in the Yazoo-Mississippi Delta, as will be seen from Table I.

TABLE I.

[From the Reports of the Thirteenth Census.]

	United States	Mississippi.	Yazoo-Mississippi Delta.
Per cent tenants form of all farmers.....	37.0	66.1	92.0
Average acres per farm operated by—			
Owners—			
Total.....	151.6	127.3	123.4
Improved.....	78.5	45.8	54.8
Tenants—			
Total.....	96.2	34.5	23.1
Improved.....	66.4	25.5	21.6
Per cent negroes form of rural population ^a	14.5	57.5	88.3
Per cent negro tenants form of all tenants.....	23.7	59.1	95.4
Per cent of negro farmers that are—			
Owners (including part owners and managers).....	24.7	15.2	5.5
Tenants.....	75.3	84.8	94.5

^a Population outside of places having at least 2,500 inhabitants.

Ninety-two per cent of the farms in the Delta were operated by tenants. The average size of farms operated by owners was 123 acres, of which about two-fifths was improved land while the average size of the tenant farms was only 23 acres, nearly all improved. The average investment in land and buildings on farms operated by owners was \$5,326 and on farms operated by tenants \$1,230. Seven-eighths of the rural population is negro, and negroes form 95.4 per cent of all the farm tenants.

METHOD OF INVESTIGATION.

This investigation is based on 878 records which were secured from planters or from managers of plantations and refer to the business of several representative tenants on each plantation during the year 1913. The information sought was comparatively easy to secure because the transactions involved were few; nearly all of the cash income was derived from the sale of cotton and of cotton seed and sometimes of corn, while the items of expenditure were very largely confined to those for feed and for hired labor, together with depreciation, repair, and insurance charges on buildings and machinery. The investigation did not cover loans or advances by planters to tenants, but was confined to the study of the agricultural returns under the different methods of renting.

The location of the farms from which records were secured is shown by figures on the accompanying map (fig. 1).

The records were secured in March and April, 1914, and referred to the crop year 1913. The cotton crop for that year was better than the average, and the corn crop was about average, being rather poor in the extreme southern part of the territory. Table II shows the average yield of cotton and of corn in each of the nine counties wholly included in the Delta, as reported by the Census for 1909, as estimated for 1910, 1911, 1912, and 1913, and as found on the plantations visited during this investigation. For the entire territory the cotton yield on the land investigated was 0.66 bale per acre as compared with 0.47, the average for 1909-1913, while the corn yield was 24 bushels per acre in each case.

TABLE II.

County.	Yield per acre of cotton (bales).						
	Census 1909.	Estimates.				Average 1909-1913.	Raised in 1913 by tenants investi- gated.
		1910	1911	1912	1913		
Bolivar.....	0.38	0.50	0.33	0.58	0.64	0.49	0.57
Coahoma.....	.48	.45	.36	.48	.55	.46	.71
Issaquena.....	.49	.61	.42	.50	.35	.47	.51
Leflore.....	.38	.44	.40	.59	.64	.49	.69
Quitman.....	.50	.41	.46	.62	.66	.53	.60
Sharkey.....	.45	.52	.32	.42	.56	.45	.63
Sunflower.....	.40	.47	.33	.59	.67	.49	.78
Tunica.....	.47	.33	.45	.39	.42	.41	.52
Washington.....	.49	.53	.30	.50	.59	.48	.77
Average for 9 counties.....	.43	.46	.35	.53	.59	.47	.66
	Yield per acre of corn (bushels).						
Bolivar.....	18	(a)	26	25	33	26	19
Coahoma.....	23	(a)	20	35	22	25	28
Issaquena.....	19	(a)	27	20	10	19	23
Leflore.....	18	(a)	25	28	20	23	23
Quitman.....	22	(a)	(b)	(b)	(b)	22	22
Sharkey.....	19	(a)	33	(b)	18	23	21
Sunflower.....	22	(a)	28	25	35	28	22
Tunica.....	22	(a)	(b)	(b)	20	22	32
Washington.....	20	(a)	(b)	19	22	20	28
Average for 9 counties.....	20	(a)	26	26	24	24	24

a No figures available for 1910.

b No data.

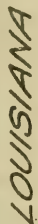


FIG. 1.—The Yazoo-Mississippi Delta. Figures show the number of records taken in each locality.

METHODS OF RENTING LAND.

Three general systems of renting land, with many variations, are practiced in the Yazoo-Mississippi Delta, each of the systems having advocates among planters and among tenants. On large plantations all three of the systems are sometimes found side by side. The main points of the three systems are described in the following paragraphs:

Half-and-half system (share croppers).—Under this system the tenant supplies the labor and one-half of the fertilizers, when any are used, while the landlord furnishes the land, a cabin, a garden plot, all the tools, the work animals and their feed, the seed, one-half of the fertilizers used, and the tenant's fuel wood, which the tenant cuts from the nearest available woodland, using the landlord's mules for hauling. Each party under this system receives half the crop and each pays for his half of the ginning, bagging, and ties. If, as happens occasionally, another crop besides corn and cotton is grown, it is also divided equally between landlord and tenant. Cowpeas are frequently planted in the corn at the last cultivation with the seed usually furnished by the landlord. In this case all the hay, if cured, goes to the landlord. The tenant is often allowed to pasture it if he has a cow or other stock. The landlords exercise careful supervision over the share croppers, who are locally not considered as tenants at all, but as laborers hired to do the work in return for half the crop and the use of a cabin.

Sometimes under this system the tenant pays cash for the use of the land not planted in cotton and for the use of the planter's equipment in working it. In such cases the tenant receives all the crops raised in this manner.

Share renting system.—Under this system the tenant furnishes his own work stock and feeds it, and also supplies tools, seeds, and all labor, while the owner provides the land, the buildings, and the fuel. If fertilizers are used under this system, they are paid for in the ratio of each party's share of the crop. The tenant pays as rent a share of the crop, one-fourth in some sections and one-third in others. The use of the land in corn is sometimes paid for in cash and the tenant then retains all the crop. Each party to this agreement pays for ginning and bagging his part of the cotton. The landlord is interested in the crop and oversees the tenant's operations, but is not so much concerned about the economical use of mules and machinery, since they belong to the tenant.

Cash renting system.—This system is similar to the share renting system, except that in lieu of a share of the crop the tenant pays a fixed rent per acre in cash or in lint cotton. Since the cotton is sold through the planter, he is sure of his rent provided a crop is raised, but since he can not collect his rent if there is no crop, and since also the tenant is usually indebted to him for supplies advanced, the

landlord exercises supervision over the cash renters, except in the case of renters whom he knows to be dependable.

Table III summarizes in convenient form the principal terms of the three systems of tenure:

TABLE III.

	Method of renting.		
	Share cropping.	Share renting.	Cash renting.
Landlord furnishes.....	Land..... House or cabin..... Tools..... Work stock..... Feed for work stock..... Seed..... One-half of fertilizers..... Fuel.....	Land..... House or cabin..... Fuel..... One-fourth or one-third of fertilizers.....	Land. House or cabin. Fuel.
Tenant furnishes.....	Labor..... One-half of fertilizers.....	Labor..... Work stock..... Feed for work stock..... Tools..... Seeds..... Three-fourths or two-thirds of fertilizers.....	Labor. Work stock. Feed for work stock. Tools. Seeds. Fertilizers.
Landlord receives.....	One-half of the crop.....	One-fourth or one-third of the crop.	Fixed amount in cash or lint cotton.
Tenant receives.....	One-half of the crop.....	Three-fourths or two-thirds of the crop.	Entire crop less fixed amount.

FACTORS OF PRODUCTION IN RELATION TO METHOD OF RENTING.

Table IV presents the relationship between the principal factors of production and the method of renting land.

TABLE IV.

	All records.	Share croppers.	Share renters.	Cash renters.
Number of records.....	878	445	136	297
Acreage in crops per tenant:				
Total.....	23.4	19.3	27.1	28.0
Cotton.....	19.5	17.0	20.9	22.6
Per cent in cotton.....	83.0	88.0	77.0	81.0
Corn.....	3.9	2.3	6.0	5.3
Yield of cotton per acre (bales).....	0.66	0.69	0.69	0.61
Yield of corn per acre (bushels).....	24.0	24.0	23.0	24.0
Average value of farm property per tenant:				
Total.....	\$2,176.00	\$1,811.00	\$2,504.00	\$2,574.00
Land.....	1,674.00	1,378.00	1,929.00	2,001.00
Buildings.....	240.00	210.00	273.00	269.00
Mules.....	222.00	194.00	248.00	253.00
Implements.....	40.00	29.00	54.00	51.00
Average value of farm property per acre:				
Total.....	92.92	93.95	92.40	92.09
Land.....	71.47	71.49	71.16	71.59
Buildings.....	10.23	10.87	10.09	9.64
Mules.....	9.49	10.07	9.15	9.03
Implements.....	1.73	1.52	2.00	1.83
Average number of mules per tenant.....	1.36	1.03	1.69	1.68
Average value of mules.....	\$164.00	\$187.00	\$147.00	\$150.00
Average number of crop acres per mule.....	17.3	18.5	16.1	16.7
Average number of bales of cotton per mule.....	9.5	11.2	8.5	8.3
Average labor income.....	\$392.00	\$333.00	\$398.00	\$478.00
Average amount earned by outside labor.....	23.00	27.00	25.00	15.00
Average value of family labor.....	118.00	103.00	139.00	132.00
Average value of hired labor.....	56.00	31.00	72.00	85.00
Proportion of total income received by labor (per cent).....	73.0	67.0	70.0	82.0
Average rate of interest on landlord's investment (per cent).....	10.6	13.6	11.8	6.6

It will be seen that cash renters and share renters had, on the average, 28 and 27 acres of cultivated land, respectively, while share croppers had only 19 acres. The share croppers' land was more exclusively devoted to cotton than that of the renters.

The yield of cotton per acre was 0.69 bale for share croppers and share renters, as compared with 0.61 for cash renters, indicating that the cash renters produce smaller crops than the share renters or share croppers, in the magnitude of whose crop the landlord is directly concerned. The assumption that the landlords sometimes assign the poorer land to cash renters since yield per acre does not directly concern the landlord, is not borne out by Table IV.

The average investment was considerably less (\$1,811) in holdings of share croppers than in those of share renters (\$2,504) or of cash renters (\$2,574), but the difference was due very largely to the fact that the share croppers' holdings were smaller, since the value of land and of buildings per acre did not differ materially for the different types of tenants. The average value of tools, however, was only \$1.52 per acre on share croppers' land, as compared with \$2 on share renters' and \$1.83 on cash renters', indicating that less machinery is used on share croppers' holdings. Owing to cooperation, the machinery is generally more fully utilized by share croppers than by the other tenants.

A difference worth noting is that for share croppers, where the mules are supplied by the landlord, the average value of mules was \$187, while for share renters it was \$147 and for cash renters \$150. The landlords supply better mules than do the tenants and see to it that good use is made of the mules, the average number of bales of cotton and the average number of acres cultivated per mule being considerably greater where the mules belong to the landlords than where they belong to the tenants.

The labor income of tenants was \$333 for share croppers, \$398 for share renters, and \$478 for cash renters. By labor income is meant the amount the farmer gets for his individual year's work exclusive of the use of a house and the food and fuel furnished by the farm. It is computed by subtracting from the net receipts all expenses, including value of unpaid family labor, as well as interest on investment and allowances for depreciation and repairs.¹ It

¹ The items of expenditure were determined by obtaining estimates from the 160 planters interviewed, each planter's figures being used on the records for his plantation. The averages of the estimates given by the planters for the various items of expenditures were as follows:

Depreciation and insurance on buildings.....	per cent..	6.0
Repairs on buildings.....	do....	4.5
Depreciation of mules.....	do....	10.4
Depreciation of implements and tools.....	do....	20.7
Repairs of implements and tools.....	do....	13.2
Cost of feeding one mule.....		\$94.00
Cost of ginning and wrapping per bale.....		\$3.50
Cost of overseeing per acre.....		\$1.51

appears that the tenant, on the average, receives more for his labor on land rented for cash and on the share renters' land than on land operated by share croppers. This difference is probably influenced but not entirely accounted for by the size of holdings, the labor income being \$18 per acre for cash renters, \$17 for share croppers, and \$15 for share renters. The relationship between labor income and type of tenure is further considered on page 10.

A question of importance is, what share of the total income produced on the land rented by the different methods remains in the hands of the persons who work the land, after the landlord has been paid? The total amount received by labor is the sum of the labor income, including money earned by work outside of the farm, plus the value of the unpaid labor of the tenant's family, and the cost of hired labor. Out of every dollar earned by the farms included in this study 73 cents went to labor. This amount is much higher than corresponding amounts in other sections of the country studied by the Office of Farm Management; in the corn belt labor receives about 50 cents out of every dollar of income, and in some of the intensive farming regions of the east, 53 cents. The cash renters in the Delta retained 82 cents out of every dollar earned; the share renters, 70 cents; and the share croppers, 67 cents.

The average rate of interest on the landlord's investment was 13.6 per cent on land rented to share croppers, 11.8 per cent on land in the hands of share renters, and 6.6 per cent on land operated by cash renters.

No allowance has been made in these rates for taxes paid by the landlord on his land, so that about 1 per cent should be subtracted from the above figures to obtain the net earnings on the investment. The relationship between the landlord's profits and the system of tenure is further discussed on page 12.

A measure of the productivity of the tenants' labor under the different systems of tenure may be obtained by comparing the amounts produced by the tenants, after subtracting the value of the labor of the tenants' families and of hired labor. (Table V.)

TABLE V.

Per tenant.	All tenants.	Share croppers.	Share renters.	Cash renters.
Value of cotton sold				
Lint	\$845	\$757	\$940	\$932
Seed	139	126	151	153
Value of corn raised	72	40	100	100
Value of labor performed outside of farm	23	27	25	15
Total value of products and of outside labor	1,079	950	1,216	1,200
Value of family labor and of hired labor	174	134	211	217
Value produced by tenant	905	816	1,005	983

The share cropper produced \$816, the share renter \$1,005, the cash renter \$983. This difference in productivity may be due in part to the relative size of the holdings of the different classes of tenants, but is more directly attributable to the greater amount of family labor and hired labor employed by the renters, since the value of the additional crop produced by the labor is greater than the wages paid. It may also be that cash renters and share renters, as a class, are more industrious than share croppers.

LABOR INCOME IN RELATION TO METHOD OF RENTING.

Table VI shows the number and the percentage of each class of tenants whose labor income fell in each specified group, and the average labor income for each group. The accompanying chart (fig. 2) presents the percentages graphically.

TABLE VI.

Class of tenants.	Total.	Labor income.											
		Deficit.	Under \$100.	\$100 to \$199.	\$200 to \$299.	\$300 to \$399.	\$400 to \$499.	\$500 to \$599.	\$600 to \$699.	\$700 to \$799.	\$800 to \$899.	\$900 to \$999.	\$1,000 and over.
		Number having each income.											
All tenants.....	878	18	35	105	194	209	123	62	39	34	19	9	81
Share croppers.....	445	1	12	57	123	143	61	26	12	6	2	-----	2
Share renters.....	136	4	7	20	21	25	23	10	8	8	5	1	4
Cash renters.....	297	13	16	28	50	41	39	26	19	20	12	8	25
		Per cent having each income.											
All tenants.....	100.0	2.0	4.0	12.0	22.1	23.8	14.0	7.1	4.4	3.9	2.2	1.0	3.5
Share croppers.....	100.0	.2	2.7	12.8	27.6	32.1	13.7	5.8	2.7	1.4	.5	-----	.5
Share renters.....	100.0	2.9	5.1	14.7	15.4	18.4	16.9	7.4	5.9	5.9	3.7	.7	3.0
Cash renters.....	100.0	4.4	5.4	9.4	16.9	13.8	13.1	8.8	6.4	6.7	4.0	2.7	8.4
		Average income for each income group.											
All tenants.....	\$392	\$64	\$63	\$156	\$249	\$345	\$447	\$542	\$649	\$746	\$857	\$950	\$1,344
Share croppers.....	333	126	68	162	250	342	447	536	648	752	887	-----	1,455
Share renters.....	398	77	62	154	256	348	447	542	626	750	847	910	1,220
Cash renters.....	478	56	59	146	245	354	448	547	656	743	856	956	1,355

Only one of the share croppers had a deficit during the year, that is, received less for his share of the cotton than the value of his family's labor, and only 2.7 per cent of them made less than \$100; the great majority of the share croppers (86.3 per cent) had labor incomes of between \$100 and \$499, and only one-tenth of them made as much as \$500. Of the share renters 2.9 per cent reported deficits and 5.1 per cent positive incomes of less than \$100; about two-thirds made between \$100 and \$499, and more than one-fourth made \$500 and over. In the case of cash renters 4.4 per cent lost money and 5.4

per cent made less than \$100; but only a little more than one-half (53 per cent) had labor incomes of between \$100 and \$499, and 37 per cent made \$500 or more, as many as 25, or 8.4 per cent, being in the \$1,000 and over class. Thus the share croppers run a smaller risk of losses or of incomes below \$100, but on the other hand only one-tenth of them rise above \$500 and almost none above \$1,000. In the case of the share renters there are more failures, more very small incomes, but also more incomes of over \$500; while of the cash renters about one-tenth make less than \$100, a little more than one-half make between \$100 and \$499, and more than one-third make \$500 or more.

Table VII brings out the differences between the earnings of the three classes of tenants in a different manner. This table shows what

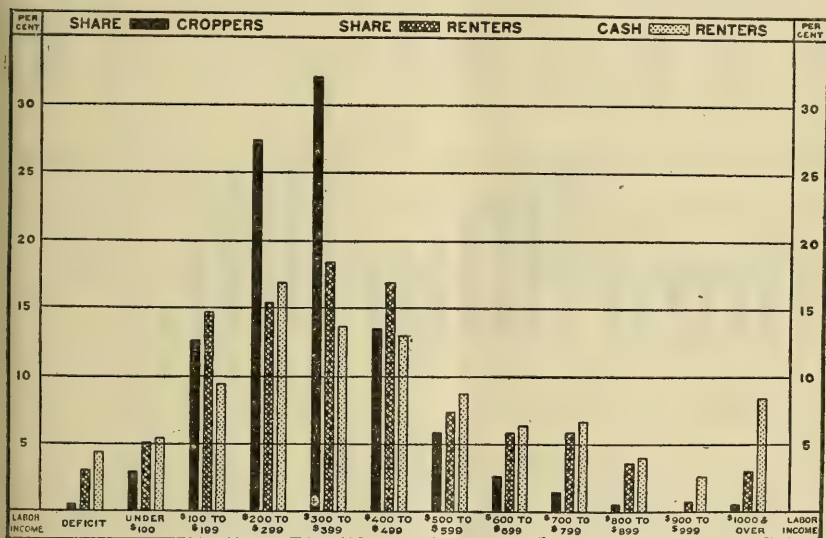


FIG. 2.—Percentage of tenants in each labor income group.

proportion of each class of tenants made labor incomes of not less than \$100, not less than \$200, etc. Of the share croppers 84.3 per cent made at least \$200, as compared with 77.3 per cent of the share renters and 80.8 per cent of the cash renters, but of the share croppers only 24.6 per cent made as much as \$400, of the share renters 43.5 per cent and of the cash renters 50.1 per cent; so that cash renters had twice as good a chance of making not less than \$400 for their labor as did share croppers. The difference in favor of the cash renters becomes even greater in the higher income groups, the share renters always occupying an intermediate position between the other two classes. For instance, only one share cropper in a hundred made as much as \$800, as compared with 7 share renters and 15 cash renters; only one share cropper in 200 made a labor income of as much as \$1,000, as

compared with one in 33 share renters and one in 12 cash renters. The risk in share cropping is the smallest, but so is the possible reward, while in cash renting both the risks and possible rewards are much higher. When all the cases are averaged, however, it appears that cash renters make one-half again as much as share croppers, while share renters make about one-fifth more than share croppers.

TABLE VII.

Amount of income.	Percentage having a labor income of not less than each specified amount.				Amount of income.	Percentage having a labor income of not less than each specified amount.			
	All tenants.	Share croppers.	Share renters.	Cash renters.		All tenants.	Share croppers.	Share renters.	Cash renters.
0.....	98.0	98.8	97.1	95.6	\$600....	15.0	5.1	19.2	23.2
\$100.....	94.0	97.1	92.0	90.2	700....	10.6	2.4	12.3	21.8
200.....	82.0	84.3	77.3	80.8	800....	6.7	1.0	7.4	15.1
300.....	59.9	56.6	61.9	63.9	900....	4.5	0.5	3.7	11.1
400.....	36.1	24.6	43.5	50.1	1,000....	3.5	0.5	3.0	8.4
500.....	22.1	10.1	26.4	37.0					

LANDLORDS' PROFITS IN RELATION TO TENANTS' LABOR INCOME.

Table VIII shows the rate of interest received by landlords on their investment in farms whose tenants made each specified labor income. The accompanying chart (fig. 3) shows the relationship graphically.

TABLE VIII.

Class of tenants.	Labor income.							
	All tenants.	Deficit.	Under \$100.	\$100 to \$299.	\$300 to \$499.	\$500 to \$699.	\$700 to \$999.	\$1,000 and over.
	Number of tenants in each labor income group.							
All tenants.....	878	18	35	299	332	101	62	31
Share croppers.....	445	1	12	180	204	38	8	2
Share renters.....	136	4	7	41	48	18	14	4
Cash renters.....	297	13	16	78	80	45	40	25
	Average rate of interest on landlord's investment on holdings of tenants in each labor income group.							
All tenants.....	10.6	7.0	5.5	8.2	12.7	13.2	9.6	10.2
Share croppers.....	13.6	1.1	3.1	8.7	15.5	19.8	18.2	25.7
Share renters.....	11.8	7.1	8.0	9.2	12.4	13.3	14.8	16.6
Cash renters.....	6.6	8.0	5.7	6.8	6.7	6.4	6.0	7.1

The landlord made only 1.1 per cent on his investment in the case of the share cropper who lost money and only 3.1 per cent where the tenant made under \$100, but the rate increased rapidly with the tenants' labor income, and in the cases where the tenant made as much as \$1,000 he gave the landlord a return of over 25 per cent

in his investment. In case of the share renters the landlord in no group averaged less than 7.1 per cent and his rate of interest rose as high as 16.6 per cent where the tenant had a labor income as high as \$1,000. In the case of cash renters the landlord's rate of interest varied within much narrower limits, the lowest being 5.7 per cent, where the tenants made less than \$100, and the highest, 8 per cent, where the tenants reported a deficit.

The variations in the rates of the landlords' interest are somewhat irregular owing to the small numbers involved, but in general it is clear that the landlord takes the greatest chances and, when successful, reaps the highest rewards from share croppers; with share renters the

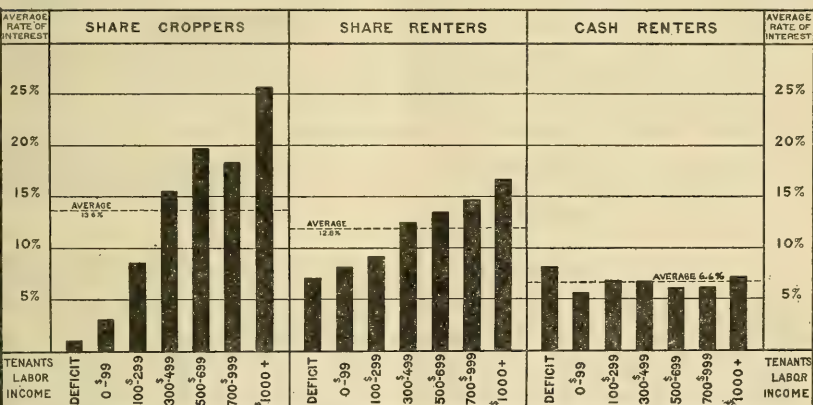


FIG. 3.—Rate of interest on landlords' investments in relation to tenants' labor income.

risks are less, and so are the possible rewards; while with cash renters the landlord takes a minimum risk and is assured of a return of 6 or 7 per cent on his investment, which is less than he would ordinarily receive for money loaned in this locality with land as security.

TENANT'S LABOR INCOME AND LANDLORD'S PROFITS IN RELATION TO ACREAGE IN COTTON AND YIELD PER ACRE.

It has been seen (page 7) that the share croppers averaged 17 acres in cotton, as compared with 20.9 acres for share renters and 22.6 acres for cash renters. Table IX shows the actual number and the percentage of each class of tenants that had a cotton acreage within each specified size group. A derivative table showing the percentage having not less than each acreage in cotton is also presented (Table X).

TABLE IX.

Acres in cotton.	Number of each class of tenants that have each specified acreage in cotton.				Percentage of each class of tenants that have each specified acreage in cotton.			
	All tenants.	Share croppers.	Share renters.	Cash renters.	All tenants.	Share croppers.	Share renters.	Cash renters.
Total.....	878	445	136	297	100.0	100.0	100.0	100.0
Under 5 acres.....								
5 to 9 acres.....	30	22	1	7	3.4	5.0	0.7	2.4
10 to 14 acres.....	205	139	25	41	23.4	31.2	18.4	13.8
15 to 19 acres.....	291	167	39	85	33.1	37.5	28.7	28.6
20 to 24 acres.....	173	79	28	66	19.7	17.8	20.6	22.2
25 to 29 acres.....	70	17	25	28	8.0	3.8	18.4	9.5
30 to 34 acres.....	51	8	13	30	5.8	1.8	9.6	10.1
35 to 39 acres.....	23	5	1	17	2.6	1.1	.7	5.7
40 to 44 acres.....	15	4	3	8	1.7	.9	2.2	2.7
45 to 49 acres.....	9			9	1.0			3.0
50 acres and over.....	11	4	1	6	1.3	.9	.7	2.0

TABLE X.

Acreage in cotton.	Percentage of each class of tenants having not less than each specified acreage in cotton.		
	Share croppers.	Share renters.	Cash renters.
Not less than—			
5 acres.....	100.0	100.0	100.0
10 acres.....	95.0	99.3	97.6
15 acres.....	63.8	80.9	83.8
20 acres.....	26.3	52.2	55.2
25 acres.....	8.5	31.6	33.0
30 acres.....	4.7	13.2	23.5
35 acres.....	2.9	3.6	13.4
40 acres.....	1.8	2.9	7.7
45 acres.....	.9	.7	5.0
50 acres.....	.9	.7	2.0

Each of the tenants studied had at least 5 acres of cotton; of the share croppers 95 per cent had 10 acres or more, of the share renters 99.3 per cent, and of the cash renters 97.6 per cent. Less than two-thirds of the share croppers had as much as 15 acres, and only about one-fourth had 20 acres or more, while of the share renters and of the cash renters the majority had 20 acres or more and about one-third had 25 acres or over. The proportion of share croppers having as much as 30 acres was only 4.7 per cent, and in the groups above that acreage the proportion was insignificant. Of the cash renters nearly one-fourth had as much as 30 acres in cotton, more than one-eighth had 35 acres, 7.7 per cent had 40 acres, 5 per cent had 45 acres, and 2 per cent had 50 acres or more. Relatively nearly as many of the share renters as of the cash renters had 25 acres or over, but considerably fewer share renters had a larger acreage, and only one had as much as 50 acres.

Table XI shows the relationship between size of cotton acreage, tenant's labor income, and rate of interest on landlord's investment.

TABLE XI.

Class of tenants.	Tenants having each specified acreage in cotton.				
	Total.	Under 15 acres.	15-19 acres.	20-24 acres.	25 acres and over.
All tenants:					
Number having each acreage	878	235	291	173	179
Per cent having each acreage	100.0	26.8	33.1	19.7	20.4
Average labor income	\$392	\$293	\$332	\$387	\$622
Rate of interest on landlord's investment	10.6	12.0	10.5	11.4	9.4
Share croppers:					
Number having each acreage	445	161	167	79	38
Per cent having each acreage	100.0	36.2	37.5	17.8	8.5
Average labor income	\$333	\$285	\$314	\$388	\$493
Rate of interest on landlord's investment	13.6	13.8	12.6	15.1	13.3
Share renters:					
Number having each acreage	136	26	39	28	43
Per cent having each acreage	100.0	19.1	28.7	20.6	31.6
Average labor income	\$398	\$334	\$308	\$386	\$525
Rate of interest on landlord's investment	11.8	10.8	10.4	12.1	12.6
Cash renters:					
Number having each acreage	297	48	85	66	98
Per cent having each acreage	100.0	16.2	28.6	22.2	33.0
Average labor income	\$478	\$295	\$380	\$386	\$714
Rate of interest on landlord's investment	6.6	6.6	6.6	6.6	6.5

The labor income of the tenants increases steadily, with but one exception, with the increase in the acreage of cotton. The principal reason why the cash renters make a much higher average labor income is that one-third of them have 25 or more acres in cotton. The difference in average labor income between the classes of tenants is not so marked on the smaller holdings, but becomes very decided on holdings of 25 acres or more. This point is brought out in Table XII, in which the average labor income in each size group is figured for share renters and cash renters on the basis of 100 for share croppers.

TABLE XII.

Class of tenants.	Average labor income in holdings falling within each size group (on basis of 100 for share croppers).			
	Under 15 acres.	15 to 19 acres.	20 to 24 acres.	25 acres and over.
Share croppers.....	100	100	100	100
Share renters.....	117	98	99	107
Cash renters.....	104	121	99	145

The figures suggest the conclusion that the method of renting land is comparatively unimportant on small holdings where the labor income of all classes of tenants is low, but where the tenant has as much as 25 acres in cotton, the cash renters have a decided advantage over the other tenants.

The rate of interest on the landlord's investment varies but little with the acreage in cotton, but there seems to be a tendency for the rate to be slightly higher on the larger holdings of share croppers and share renters and on the smaller holdings of cash renters.

A study of the relationship between size of holdings and yield of cotton per acre seems to indicate, as is shown in Table XIII, that the yields vary but little and rather irregularly in holdings of different sizes, with a tendency for somewhat larger yields on smaller holdings.

TABLE XIII.

Class of tenants.	Average yield of cotton per acre for tenants whose cotton acreage falls within each size group.				
	All classes.	Under 15 acres.	15 to 19 acres.	20 to 24 acres.	25 acres and over.
All tenants.....	0.66	0.73	0.64	0.65	0.65
Share croppers.....	.69	.75	.65	.69	.65
Share renters.....	.69	.75	.63	.70	.69
Cash renters.....	.61	.64	.61	.57	.63

Table XIV shows the relation between yield of cotton per acre, tenant's labor income, and landlord's profits.

The two accompanying charts (figs. 4 and 5) show this relationship graphically.

TABLE XIV.

Class of tenants.	Tenants having each specified yield of cotton per acre (in bales).				
	Total.	Under 0.6.	0.6 to 0.8.	0.8 to 1.	1 and over.
All tenants:					
Number having each yield.....	878	235	291	173	179
Per cent having each yield.....	100.0	26.8	33.1	19.7	20.4
Average labor income.....	\$392	\$246	\$435	\$504	\$624
Average rate of interest on landlord's investment (per cent).....	10.6	7.0	10.3	15.8	16.4
Share croppers:					
Number having each yield.....	445	161	167	79	38
Per cent having each yield.....	100.0	36.2	37.5	17.8	8.5
Average labor income.....	\$333	\$235	\$321	\$426	\$458
Average rate of interest on landlord's investment (per cent).....	13.6	7.1	13.4	19.6	19.9
Share renters:					
Number having each yield.....	136	26	39	28	43
Per cent having each yield.....	100.0	19.1	28.7	20.6	31.6
Average labor income.....	\$398	\$194	\$437	\$526	\$753
Average rate of interest on landlord's investment (per cent).....	11.8	8.3	12.6	13.4	14.5
Cash renters:					
Number having each yield.....	297	48	85	66	98
Per cent having each yield.....	100.0	16.2	28.6	22.2	33.0
Average labor income.....	\$478	\$272	\$577	\$791	\$1,256
Average rate of interest on landlord's investment (per cent).....	6.6	6.7	6.4	6.0	8.1

The yield of cotton per acre is the determining factor in the profits of farming in the Yazoo-Mississippi Delta. Where the yield was as much as a bale of cotton per acre the tenant made \$624 for his labor

and the landlord received 16.4 per cent on his investment, while where the yield was less than 0.6 of a bale the tenant had a labor income of \$246 and the landlord only made 7 per cent on his money.

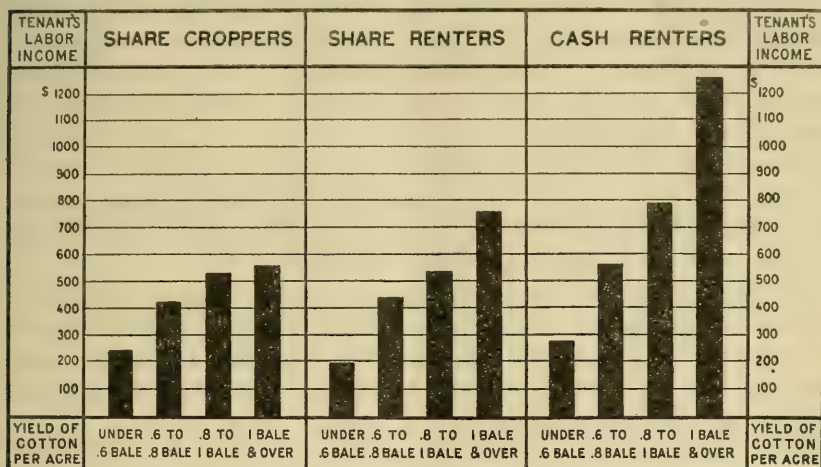


FIG. 4.—Tenants' labor income in relation to yield of cotton per acre.

The labor income goes up with the yield of cotton for all classes of tenants, but the rise is least pronounced for share croppers and most pronounced for cash renters. Thus the labor income of a share

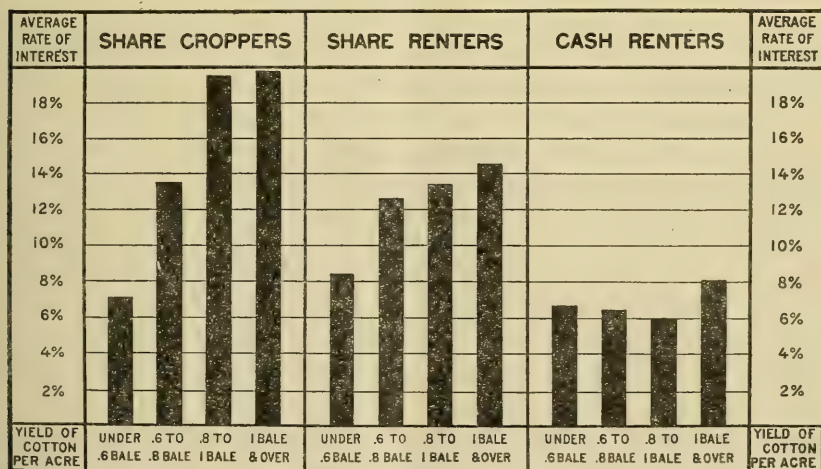


FIG. 5.—Rate of interest on landlords' investment in relation to yield of cotton per acre.

cropper was not quite twice as great where the yield was a bale or more as where it was under 0.6 of a bale, while the labor income of a share renter was nearly four times as great, and that of a cash

renter more than four and one-half times as great where the yield was high as where it was low.

The situation is reversed as regards the interest on the landlord's investment. The rate on share croppers' holdings was nearly three times as great where the yield was a bale or more as where it was under 0.6 of a bale, on share renters' holdings it was one and three-fourths times as great and on cash renters' it was about one and one-fifth times as great.

Thus, while the landlord is interested in good yields for his tenant, no matter what the nature of his contract, the landlord gains a great deal more by higher yields in the case of share croppers than he does in the case of share renters or of cash renters.

The landlord, it will be observed, has a greater object to serve by keeping a close supervision over his share croppers, and, furthermore, his supervision is the more necessary for this class of tenants, inasmuch as they themselves are not so greatly benefited by a higher yield as are the other types of tenants.

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W. J. Spillman, Chief

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MACHINERY COST OF FARM OPERATIONS IN WESTERN NEW YORK.

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Farm machinery is utilized to the best advantage when it is used in profitable work continuously until it is worn out.¹ If a mower will give 50 days of actual service, it would be more economical to wear it out in 50 days of continuous service than by working it 5 days a year for 10 years. If such a mower costs \$45, and money is worth 6 per cent, the total cost of using the mower 50 days, not counting repairs, is \$45 plus 37½ cents interest. But if the mower is used for 50 days spread out over 10 years, the total cost rises to \$45 plus \$14.85 interest,² and the interest charge per acre or per ton of hay becomes 40 times as great as in the first instance. There is also a replacement cost; that is, the sum which must be charged against the machine annually to provide for getting a new machine when it wears out, which tends to make it more economical to make the most of a machine while it is comparatively new. If machinery could be kept from deteriorating from rust and decay, this replacement cost per

¹ In addition to cost of operation, the use of farm machinery entails three kinds of expense, as follows: (1) To provide for the replacement of the implement when it is worn out; (2) to pay interest on the cost of the machine; and (3) to keep it in repair. These are referred to in the following text and tables as replacement cost, interest charge, and repairs, respectively. In most cases there is also more or less expense for shelter for the machinery.

² If the mower lasts 10 years, 10 per cent being charged off annually for replacement, the average amount upon which 6 per cent interest is earned is \$24.75, the interest on \$24.75 for 10 years at 6 per cent being \$14.85.

acre or per bushel or ton would be constant, but in actual practice a machine used but a few days per year lasts only a little longer than a similar machine used twice as much. Thus the replacement cost per acre depends largely on the number of days per year the machine is used.

From the standpoint of good management, therefore, the farmer should try to organize his business so as to obtain the maximum of profitable use annually from his machinery equipment, thereby reducing the machinery cost per day of work to the minimum.

The study upon which this bulletin is based was made with a view to gathering facts and figures which might be of value to the farmer in his efforts to cut machinery cost. To this end figures were obtained to determine the average number of years of service given by each of the various implements in use in the part of New York where the investigation was made, and from the average life of each implement and its cost when new the approximate cost of its operation has been calculated.

SUMMARY OF RESULTS.

Briefly summarized, these are the more important facts brought out or substantiated by this investigation:

The more days' work done annually by an implement the greater is its total of days and acres of work done before wearing out.

The average farm machine used in this section is less than half worn out by use alone.

The more days of actual use obtained annually from an implement the less the interest charge per acre and per day actually used.

The replacement cost per acre or per bushel or ton is from two to seven or eight times as great for small acreages as for large acreages.

The farmer with a small acreage can not compete in economy in the use of machinery with the farmer having a larger business. With the best of shelter and care, the small farm can only hope to equal the replacement cost per unit enjoyed by the large farm; it can not hope to avoid higher interest charges.

As a rule, it is not profitable to build for machinery any special shelter which adds over 15 per cent to the total machinery investment on a farm.

Repair charges per machine increase with increasing use, but not in proportion to the amount of work done. In other words, repair charges per acre and per day decrease as the acreage covered annually increases.

The larger and more substantial sizes of machinery give cheaper service than the lighter sizes, since the cost for repairs is much lower for the heavy machine than for the lighter machine, while the first cost is but a fraction greater.

In Table I is summarized the average service and cost of the principal implements used in western New York. The annual service obtained is expressed in acres and in days. The total service rendered is expressed in years, days, and acres. The average cost of each implement is shown, and the machinery cost per acre, comprising depreciation, interest, and repairs, is set out for each implement.

In referring to the cost per acre covered, as shown in this table, it should be borne in mind that these figures are averages and that they do not show the very important bearing which variation in the acreage covered annually has upon the cost per acre of using a machine. This relation is brought out strikingly in the tables that follow. For example, it will be shown that where a mower covers but 13.8 acres annually it costs the owner 36 cents per acre, while the mower that covers 53.6 acres annually costs but 10 cents per acre cut.

TABLE I.—*Summary, showing average service rendered by 18 kinds of farm implements in western New York, and average machinery cost per acre.*

Implement.	Average days' work per year.	Life of implement.		Acres covered.		Cost per acre covered.				Cost, new.
		Days of work.	Years.			Re- place- ment.	Inter- est.	Re- pairs.	Total.	
Walking plow.....	19.2	224	11.7	32.9	384.9	\$0.026	\$0.010	\$0.062	\$0.098	\$10.00
Sulky plow.....	14.7	119	8.1	30.9	250.3	.170	.046	.069	.285	42.50
Spring-tooth harrow.....	6.6	73	11.0	71.1	782.1	.023	.007	.011	.041	17.50
Spike-tooth harrow.....	3.1	43	14.0	48.3	676.2	.016	.007	.007	.030	10.50
Disk harrow.....	4.2	54	13.0	35.2	457.6	.059	.025	.014	.098	27.00
Land roller.....	4.7	75	16.0	65.9	1,054.4	.023	.011	.007	.041	24.00
Grain drill.....	4.6	76	16.4	46.3	759.3	.095	.049	.027	.171	72.00
Corn planter, 1-row.....	.9	10	11.7	4.1	48.0	.250	.111	.170	.531	12.00
Corn planter, 2-row.....	.8	9	11.0	8.2	91.3	.440	.158	.200	.798	40.00
Cultivator, 1-row.....	4.1	58	14.0	16.9	236.6	.027	.012	.021	.060	6.50
Cultivator, 2-row.....	5.6	70	12.5	39.3	491.3	.065	.027	.025	.117	32.00
Cabbage transplanter.....	3.4	43	12.8	12.5	160.0	.280	.114	.091	.485	45.00
Mower.....	3.1	46	14.8	28.0	414.4	.099	.047	.065	.211	41.00
Hay rake.....	2.6	37	14.5	43.0	623.5	.038	.019	.008	.065	24.00
Hay tedder.....	1.5	21	14.0	21.6	302.4	.112	.051	.019	.182	34.00
Bean harvester.....	2.3	29	12.9	16.9	218.0	.115	.048	.060	.223	25.00
Grain binder.....	3.4	53	15.4	35.2	542.1	.231	.113	.058	.402	125.00
Corn binder.....	3.7	40	10.8	21.1	227.9	.550	.194	.096	.840	125.00

SCOPE OF INQUIRY.

Under actual conditions on the farm there are other factors than use which affect the service obtained from farm machinery. These are (1) exposure to the weather, (2) care in operation, and (3) design and material used in the construction of the implements. No attempt was made in this inquiry to determine the relative influence of exposure, care, and design on the total service rendered by farm implements. The sole purpose was to determine how much service standard farm machinery gives in western New York under the average of the conditions existing there. No mechanical or engineering features were considered.

The larger the acreage the farmer has over which he profitably can work a machine, the more able is he to afford a well-built article of good design. There is no doubt, also, that farmers having large capital and business will average better as operators of machinery than will men who are content or obliged by personal limitations to operate a small business. Data obtained in this section regarding repairs also indicate that farmers having the larger acreages to work do so with the lower repair charges per acre. This is due, partly at least, to the fact that some repairs are made necessary because of deterioration when the machinery is idle. But it is probably also due in part to the fact that the better managers on the large farms make repairs, adjustments, and give other needed attention promptly, thereby reducing the repair costs and obtaining more units of work from each implement. The economic aspects of expenditure to shelter farm machinery from exposure to the elements are referred to hereafter.

SOURCES OF DATA.

An inquiry addressed to several thousand farmers in Niagara, Orleans, Monroe, Wayne, Genesee, Livingston, and Ontario Counties in western New York afforded a considerable mass of data from which the utility of farm machinery in this section has been determined. Facilities for housing machinery in this section are very much better than the average the country over, the natural thrift of the farmers leading them to house such property as much as possible. On account of the large amount of rainfall, hay and grain crops are usually stored in the relatively large barns typical of the area, so that during the summer months many farm implements stand out exposed to the weather until the barns are emptied of these bulky crops. At other seasons, however, the machinery is well housed. In mechanical ability there is no doubt that the farmers in this section are the equal of any.

In response to the inquiry reports were obtained for 1,165 walking plows, 294 sulky plows, 1,169 spring-tooth harrows, 824 spike-tooth harrows, 738 disk harrows, 1,173 land rollers, 1,061 grain drills, 72 one-row corn planters, 97 two-row corn planters, 1,114 one-horse cultivators, 881 riding cultivators, 217 cabbage transplanters, 359 engine sprayers, 1,232 mowers, 1,217 hay rakes, 416 hay tedders, 563 bean harvesters, 1,028 grain binders, and 458 corn binders. The bean harvesters, cabbage setters, and corn binders are used chiefly in Livingston and Genesee Counties, while the engine sprayers have their widest use in the fruit-growing counties along the lake. The other implements are used on nearly every farm. Corn is planted almost entirely with the grain drill, few corn planters being used.

METHOD OF COMPUTING MACHINERY REPLACEMENT COSTS.

There are a number of ways in which replacement costs may be computed and distributed, but a discussion of these methods and their application to the various types of business and conditions where they are in vogue would be out of place here.

The method chosen as being best adapted for use on the farm consists in charging off annually a part of the first cost of the implement in proportion to its use on the farm and under field conditions. Thus by reference to Table II for walking plows, the service rendered by a plow that covers 15.6 acres annually is 12.5 years, so that the part that should be set aside annually to provide for the replacement of this plow ($1 \div 12.5$) is 8 per cent of the first cost of the plow. In other words, the replacement charge per year, per acre, or per day is based on proportional use and not on the market valuation or sale price of the equipment at any time during its life. From the standpoint of the man on the farm who expects to remain in the business, this is a logical method to use. To the great majority of farmers, who intend to continue in the farming business for periods exceeding the duration of the life of their machinery, the tables which follow will be found useful in estimating the machinery cost of proposed work and the fair charge against work already done. To the man expecting to discontinue farming and sell his machinery, or to the man negotiating for the purchase of second-hand implements, knowledge of the further units of work that may be expected from machinery that has already performed a given amount will assist in determining its fair value to both buyer and seller.

METHOD OF COMPUTING THE INTEREST CHARGE.¹

Where a part of the first cost of equipment is charged off annually to provide for its replacement, the average investment upon which interest must be allowed is shown in the schedule below:

Fraction of cost new charged off annually.	Average investment (per cent of first cost).	Fraction of cost new charged off annually.	Average investment (per cent of first cost).	Fraction of cost new charged off annually.	Average investment (per cent of first cost).
All.....	100.00	One-eighth.....	56.25	One-fifteenth.....	53.33
One-half.....	75.00	One-ninth.....	55.55	One-sixteenth.....	53.12
One-third.....	66.66	One-tenth.....	55.00	One-seventeenth.....	52.93
One-fourth.....	62.50	One-eleventh.....	54.54	One-eighteenth.....	52.77
One-fifth.....	60.00	One-twelfth.....	54.17	One-nineteenth.....	52.63
One-sixth.....	58.33	One-thirteenth.....	53.84	One-twentieth.....	52.50
One-seventh.....	57.14	One-fourteenth.....	53.57		

¹ The average investment in equipment, where a fraction of its first cost is charged off each year for replacement, may be found by the rule: Average investment = first cost $\times \frac{\text{years of service} + 1}{\text{years of service} \times 2}$.

By multiplying the average investment by the prevailing rate of interest in the locality where the equipment is located the average annual interest charge against the equipment is found. In connection with the tables which follow the replacement cost and the interest charge have been computed by the foregoing methods in terms of the year, the acre, and the day actually used.

METHOD OF DETERMINING THE SERVICE OF FARM MACHINERY.

The farm conditions which affect the annual service rendered by machinery are so many and various in the same locality, and so different between widely separated areas, that no general method of approximating the annual depreciation is feasible. Actual records on a sufficiently large number of machines extending through a period of years long enough to determine the life in use can not be secured on account of the expense and improbable continuity of the record keeping. A method was found, however, which yielded results rapidly and gave averages based on large numbers of reports for each kind of implement,¹ this method being used in obtaining data in the limited area in western New York, which is presented in the tables that follow:

EXPLANATION OF THE TABLES.

In the tables the machines are, in most cases, grouped according to the amount of work done annually. In all cases the years of service decrease with increasing annual use, but not in the same proportion. This is due to the fact that machinery depreciates to some extent when not in use. The decrease in length of time with increased annual use would be greater than actually shown in the tables were it not for the fact that the machines used on the smaller acreages are smaller and less substantially built. The average size of the implements doing the respective amounts of annual work is shown in the third line in each table.

The service of each implement is expressed in years and acres and in days of actual use. The performance in years was found by the method already explained; the service in acres was obtained by multiplying the service in years by the average work done annually;

¹ Where the number of machines in a given area is stationary, the design and construction uniform and established, and the implement has been in use there for a period exceeding the average life of such implement, the average years of service may be found by dividing the entire number by the number one year old.

Or, under the conditions just mentioned, the average service may also be found approximately by adding the present age of the respective machines reported, dividing by the total number to obtain the average present age of the group, multiplying this average by 2 and subtracting 1. By the latter method not such large numbers are required to insure a reliable average.

In computing the service in years for the tables in this bulletin both methods were used, and, while the results were practically the same in most cases by each method, they were combined and the average taken to offset to some extent the too great influence of the occasional very old individual on the average obtained by the second method.

the work in days was found by dividing the service in acres by the normal acreage or day's work done by the implements of the respective average sizes. This normal day's work, or daily duty of the respective machines, was also obtained from the same farmers in western New York.

Following each table, the replacement cost and interest charge to correspond have been computed, using 6 per cent as the local interest rate. The interest charge for any other rate may readily be found by applying proportion to the averages here given.

THE COST OF REPAIRS.

Where ordinary care is used by the operator, the repair charges for most kinds of farm machinery used in growing crops should make up but a small proportion of the total cost of production. It is often desirable, however, to know what the average repair charge for the different machines may be in order to arrive at a fair allowance for such repairs in planning future farm work or in determining the cost of work already done. But little data have ever been made available that could be used by the man on the farm, the county agent, the agricultural instructor, or the investigator in farm organization and management, in determining the repair cost for the machinery used on any given farm enterprise.

In the same inquiry through which the data on the service of the farm machinery was obtained for western New York, the repair charges against these implements were also accumulated. In all of the tables the total amount of repairs during life is given for each implement, corresponding to the same annual service for which the replacement and interest charges have been computed. The cost of repairs per year, per day actually used, and per acre can be readily computed. Tables II to XIX afford complete data, therefore, for this area, on the machinery cost of farm operations.

DETAILED STUDY OF IMPLEMENTS.

WALKING PLOW.

From Table II, for walking plows, it appears that the average plow used in this section is about 12 inches wide; that it averages 32.9 acres of plowing annually, and lasts on the average 11.7 years. During this time it covers an average of 384.9 acres and is used a total of 224 days. Of all farm implements, the walking plow gives by far the most days of service. The heavier plows do more work annually. They also plow more acres and do more days of work before they are worn out. Since the walking plow is an implement of low cost, the interest charge is relatively low. Its long use reduces the replacement charge per acre, but the heavy work required of it makes the repair charge per acre equal that of a grain binder and exceed that for most of the other implements.

TABLE II.—*Walking plows—relation of work done annually to service and cost per acre and per day used on 1,165 farms.*

Range of area covered annually.....acres..	1 to 20.	21 to 30.	31 to 40.	41 to 50.	51 and over.	Average.
Number of records included.....	263	407	292	120	83	.....
Average area covered annually.....acres..	15.6	28.0	39.6	48.4	68.5	32.9
Years of service rendered.....	12.5	12.2	11.7	11.0	8.6	11.7
Acres covered during life.....	195.0	341.6	463.3	532.4	589.1	384.9
Days actually used during life.....	115	204	269	291	300	224
Average width of plow.....inches..	9.0	10.4	12.8	14.0	15.1	11.8
Cost when new.....	\$8.00	\$9.25	\$11.50	\$12.00	\$13.00	\$10.00
Total cost of repairs during life.....	17.25	24.64	25.27	27.28	27.95	23.99
Total interest during life at 6 per cent.....	3.25	3.66	4.45	4.84	3.78	3.86
Total of depreciation, interest, and repairs during life.....	28.50	37.55	41.22	44.12	44.73	37.85
Cost of walking plow:						
Per day used.....	\$0.248	\$0.184	\$0.153	\$0.151	\$0.149	\$0.169
Per acre plowed.....	.146	.107	.089	.082	.076	.098

The average cost of new walking plows of the average size shown in Table I is \$10. Even though the heavier plows cost more money, the machinery and interest charges per acre and per day progressively decrease, as more work is done annually by the plow. There is a uniform decrease in the cost of repairs per acre as the acreage plowed annually is increased. The size and weight of the plow also increase with the increasing acreage. The average cost per acre for repairs is \$0.062. The repairs made to a plow during its life amount to more than twice its first cost.

TABLE III.—*Sulky plows—relation of work done annually to service and cost per acre and per day used on 294 farms.*

Range of area covered annually.....acres..	1 to 20.	21 to 40.	41 and over.	Average.
Number of records included.....	89	150	55	.....
Average area covered annually.....acres..	14.3	32.8	55.1	30.9
Years of service rendered.....	11.3	7.0	6.2	8.1
Acres covered during life.....	161.6	229.6	341.6	250.3
Days actually used during life.....	83	108	150	119
Average width of plow.....inches..	11.0	13.1	16.5	13.3
Cost when new.....	\$40.00	\$45.00	\$47.50	\$42.50
Total cost of repairs during life.....	14.92	15.75	19.65	17.17
Total interest during life at 6 per cent.....	14.92	10.78	10.29	11.58
Total of depreciation, interest, and repairs during life.....	69.84	71.53	77.44	71.25
Cost of sulky plow:				
Per day used.....	\$0.841	\$0.662	\$0.516	\$0.590
Per acre plowed.....	.432	.311	.229	.284

THE SULKY PLOW.

The sulky plow (Table III) is much less generally used in western New York than is the walking plow, only 294 being reported as compared with 1,165 walking plows. Greater acreages are plowed daily per plow than with walking plows, and the number of days of work done annually by the sulky plow is somewhat less than for the walking plow. A sulky plow requires three horses for its proper operation, and this increased power applied to the implement results in greater

strain and wear on the working parts than for walking plows. The average sulky plow in this section works 119 days and plows 250 acres of land. Its cost new is over three times that of a walking plow; so that the overhead charges (replacement and interest) are five or six times as much per acre and over five times as much per day. The quality of work done by the sulky plow when properly operated is sufficiently superior to offset the greater overhead charges.

The decrease in cost per acre with increase of annual use show very conclusively the advantage of covering large acreages per plow annually.

The man with a small acreage may reduce his replacement cost somewhat by buying a lighter plow at a lower price, but even this does not eliminate the economic disadvantage under which he labors.

Sulky plows have a higher average repair charge per acre than do walking plows, the average being \$0.069. The sulky plows in general use cost from \$40 to \$45, so that the total repair charges during life average 42 per cent of the first cost of the implement. The repair charges decrease as the acreage plowed is increased, this being in part accounted for by the larger plows used on the greater acreages.

THE SPRING-TOOTH HARROW.

In Table IV is shown the performance of spring-tooth harrows. The spring-tooth harrow is an implement that gives long service in years and also in terms of acres harrowed. Because of the large areas covered daily, its life in days actually worked averages only 73. The spring-tooth harrow is an implement that is given very poor shelter, its form making it awkward to house, and it often lies out unprotected from one year's end to another. The repair charges on these harrows are also very small. From the standpoint of work done it is a machine of very high efficiency, averaging 11 years of life and 782 acres of work. Table IV, like all of the other tables, shows that the larger machines which do the most work annually also do the greatest total of acres and days before being worn out.

TABLE IV.—*Spring-tooth harrows—relation of work done annually to service and cost per acre and per day used on 1,169 farms.*

Range of area covered annually.....acres..	1 to 40.	41 to 80.	81 to 150.	151 and over.	Average.
Number of records included.....	417	408	276	68	.....
Average area covered annually.....acres..	29.5	61.0	111.6	222.3	71.1
Years of service rendered.....	11.6	11.1	10.2	8.9	11.0
Acres covered during life.....	342.0	677.1	1,138.3	1,978.5	782.1
Days actually used during life.....	39	74	96	149	73
Average width of harrow.....feet..	5.7	6.5	8.2	10.4	6.9
Cost when new.....	\$15.00	\$17.00	\$20.00	\$24.00	\$17.50
Total cost of repairs during life.....	6.15	8.88	9.28	10.86	8.25
Total interest during life at 6 per cent.....	5.92	6.22	6.73	8.16	5.83
Total of depreciation, interest, and repairs during life.....	27.07	32.10	36.01	43.02	31.58
Cost of spring-tooth harrow:					
Per day used.....	\$0.794	\$0.433	\$0.375	\$0.288	\$0.432
Per acre harrowed.....	.079	.047	.032	.021	.043

The approximate cost of new spring-tooth harrows of the average sizes shown in Table IV is \$17.50. The replacement cost for each time an acre is harrowed with the spring-tooth harrow is \$0.023, and the interest charge per acre averages about \$0.007.

The repair charges on spring-tooth harrows are very small per acre covered, being only \$0.011 on the average. The total repairs made during the life of the average spring-tooth harrow cost about 47 per cent as much as the harrow itself when new.

THE SPIKE-TOOTH HARROW.

The spike-tooth harrow (Table V) is not in such general use in this section as is the spring-tooth harrow. It is a longer-lived implement than the spring-tooth harrow by about 27 per cent in terms of years, but it does about one-third less work in terms of acres. The class of soils on which the spike-tooth harrow can be used is lighter, and the character of work required of it is much less severe. In this section the spike-tooth harrow lasts an average of 14 years, doing 43 days of work and covering 676 acres of land. Like the spring-tooth harrow and walking plow, it is a low-priced implement, so that the interest charge, as well as the machinery or replacement charge per day and per acre, is relatively low.

Spike-tooth harrows of the average size given in Table V cost when new about \$10.50. The average cost for harrowing an acre is \$0.016 for replacement and \$0.007 for interest.

TABLE V.—*Spike-tooth harrows—relation of work done annually to service and cost per acre and per day used on 824 farms.*

Range of area covered annually acres . .	1 to 20.	21 to 40.	41 to 60.	61 to 100.	101 and over.	Average.
Number of records included	193	301	151	138	41	.....
Average area covered annually acres . .	15.7	33.3	52.8	86.4	166.6	48.3
Years of service rendered	18.4	13.6	12.9	12.4	10.0	14.0
Acres covered during life	288.9	452.9	681.1	1,071.4	1,666.0	676.2
Days actually used during life	24	37	40	64	79	43
Average width of harrow feet . .	6.3	7.3	9.5	10.6	13.8	8.5
Cost when new	\$7.75	\$9.00	\$12.00	\$13.00	\$17.00	\$10.50
Total cost of repairs during life	2.76	4.22	3.35	7.32	7.70	4.76
Total interest during life at 6 per cent	4.42	3.94	5.29	5.21	5.60	4.76
Total of depreciation, interest, and repairs during life	14.93	17.16	20.64	25.53	30.30	20.02
Cost of spike-tooth harrow:						
Per day used	\$0.622	\$0.464	\$0.516	\$0.400	\$0.383	\$0.465
Per acre harrowed	.052	.038	.030	.024	.018	.029

The spike-tooth harrow is an implement having lower repair charges per acre than does the spring-tooth harrow, the average being only \$0.007 per acre. It is not subjected to the severe strains met by the spring-tooth harrow, as the latter is used on much heavier and more stony land where the spike-tooth harrow would not work

at all. The total cost of repairs during the life of the spike-tooth harrow in this section amounts to only 20 per cent of the first cost of the implement.

THE DISK HARROW.

The disk harrows used in western New York (Table VI) show an average of 13 years, 457 acres, and 54 days of actual work. The 9-foot disk harrow, working 99 acres annually, as compared with a 5½-foot disk harrow, covering 16.7 acres annually, or one-sixth as much, lasts only two years less, covers five times as much land before wearing out, and works four times as many days. The cost of the larger implement exceeds that of the smaller by only 25 to 30 per cent. The farmer who has the greatest use for a disk harrow obtains the greatest return per day and per acre on his investment.

The depreciation charge against the disk harrow averages \$0.059 per acre and the interest charge \$0.025 per acre. The disk harrow is a much more expensive implement per acre than is the spike-tooth harrow or the spring-tooth harrow. Farmers who can use the larger disk harrows drawn by larger teams working over large acreages annually are seen to have a very great advantage economically in the matter of overhead charges.

TABLE VI.—*Disk harrows—relation of work done annually to service and cost per acre and per day used on 733 farms.*

Range of area covered annually .....acres..	1 to 25.	26 to 50.	51 and over.	Average.
Number of records included.....	374	271	93	.....
Average area covered annually.....acres..	16.7	38.8	99.0	35.2
Years of service rendered.....	13.8	12.4	11.7	13.0
Acres covered during life.....	230.5	481.1	1,158.3	457.6
Days actually used during life.....	30	55	121	54
Average width of harrow.....feet..	5.5	6.8	9.0	6.4
Cost when new.....	\$25.00	\$28.00	\$32.00	\$27.00
Total cost of repairs during life.....	5.80	5.83	10.30	6.50
Total interest during life, at 6 per cent.....	11.18	11.28	12.17	11.31
Total of depreciation, interest, and repairs during life.....	41.98	45.11	54.47	44.81
Cost of disk harrow:				
Per day used.....	\$1.40	\$0.82	\$0.45	\$0.83
Per acre disked.....	.182	.094	.047	.098

Disk harrows are operated in this section at an average cost of \$0.014 per acre for repairs. From Table VI it appears the total amount of repairs during the life of the average 6-foot disk harrow is \$6.50, or about 24 per cent of the first cost of the machine.

THE LAND ROLLER.

The land roller is an implement which is subjected to a minimum of wear in use. From Table VII it is seen that a roller that covers 2,100 acres lasts nearly as long as one that covers less than 500 acres.

The roller is also damaged but little by exposure. It is one of the last implements to be housed, and often is not sheltered at all. From the standpoint of replacement, interest, and repair charges per acre, it is one of the most inexpensive implements on the farm. The average roller in western New York does 75 days of actual work, extending through a period of 16 years, covering 1,054 acres. The average replacement charge per acre is \$0.023, and the interest charge at 6 per cent is \$0.011.

TABLE VII.—*Land rollers—relation of work done annually to service and cost per acre and per day used on 1,173 farms.*

Range of area covered annually	1 to 40.	41 to 80.	81 and over.	Average.
Number of records included	425	493	255	.....
Average area covered annually	29.5	60.0	138.2	65.9
Years of service rendered	16.5	15.8	15.2	16.0
Acres covered during life	486.8	948.0	2,100.6	1,054.4
Days actually used during life	39	68	145	75
Average width of roller	7.2	8.0	10.0	8.1
Cost when new	\$20.00	\$22.00	\$25.00	\$24.00
Total cost of repairs during life	5.94	7.90	9.12	7.52
Total interest during life at 6 per cent	10.56	11.06	12.16	11.20
Total of depreciation, interest, and repairs during life	36.50	40.98	46.28	42.72
Cost of land roller:				
Per day used	\$0.93	\$0.60	\$0.32	\$0.57
Per acre rolled	.075	.043	.022	.041

Land rollers cost an average of only \$0.007 per acre for repairs. The average land roller used in this area should cost about \$24, and the total repairs necessary during its life average about 32 per cent of the original cost of the implement.

THE GRAIN DRILL.

The grain drill (Table VIII) is a comparatively expensive machine and is used only a few days in the year. The interest charge per day is therefore high. Grain drills in western New York last an average of 16.4 years in doing 76 days of work. Since they cover from 6 to 12 acres per day, the depreciation and interest charges per acre are but a small proportion of the cost of the men and horses used with them. Grain drills are substantially built, and are capable of doing many more days of work than the average farmer obtains from them.

From the computations for grain drills, it appears that there is an average depreciation charge of \$0.095 per acre and an interest charge of \$0.049 per acre. An \$85 drill, doing 75 or more acres of work annually, costs less than one-third as much per acre as a \$65 drill, doing less than 25 acres annually.

TABLE VIII.—*Grain drills—relation of work done annually to service and cost per acre and per day used on 1,061 farms.*

Range of area covered annually..... acres..	1 to 25.	25 to 50.	51 to 75.	76 and over.	Average.
Number of records included.....	272	505	195	89	.....
Average area covered annually..... acres..	20.2	40.5	65.1	117.5	46.3
Years of service rendered.....	15.5	16.6	15.7	13.9	16.4
Acres covered during life.....	353.5	672.3	1,022.1	1,633.3	759.3
Days actually used during life.....	39	67	102	160	76
Average width of drill..... feet..	5.1	6.3	6.4	7.3	6.2
Cost when new.....	\$65.00	\$72.00	\$75.00	\$85.00	\$72.00
Total cost of repairs during life.....	13.83	20.75	27.63	24.88	20.66
Total interest during life at 6 per cent.....	36.05	39.01	37.68	38.09	37.56
Total of depreciation, interest, and repairs during life.....	114.88	131.76	140.31	147.97	130.22
Cost of grain drill:					
Per day used.....	\$2.95	\$1.94	\$1.38	\$0.92	\$1.71
Per acre drilled.....	.328	.196	.137	.090	.171

Grain drills require an average repair expense of \$0.027 per acre. The average 6-foot drill used in this territory costs about \$72, and the total repairs made during its life amount to approximately 29 per cent of the cost when new.

THE CORN PLANTER.

Corn is usually planted in drills with the grain drill in western New York, so that few corn planters were reported for this section. The areas devoted to corn do not justify the purchase of a special planter for this work, as the cost of their use per day and per acre is greater than where the grain drill is employed to do the corn planting as well as the other seeding. From the limited data submitted for corn planters (Table IX), the 1-row type averages less than 1 day of use annually, while the 2-row type is used even less.

The replacement charges for corn planters costing \$12 is \$1.025 annually, or \$0.25 per acre. The interest charge is \$0.46 per annum, or \$0.112 per acre. For planters costing \$40 the corresponding charges are: Replacement, \$3.64 per annum, or \$0.438 per acre; interest, \$1.13 per annum, or \$0.136 per acre.

Corn planters are comparatively expensive tools to keep in repair. The average 1-horse planter costs \$0.69 annually for repairs and the 2-horse planter \$1.68 annually. The total repairs during the life of the 1-horse machine amount to an average of 67 per cent of its first cost, while the total for the 2-horse machine is about 46 per cent of the first cost. The average cost for repairs per acre in this section is \$0.17 for the 1-horse planter and \$0.20 for the 2-horse planter.

TABLE IX.—*Corn planters—relation of work done annually to service and cost per acre and per day used on 169 farms.*

Range of area covered annually	acres.....	1 to 5.	6 to 10.
Number of records included.....		72	97
Average area covered annually.....	acres.....	4.1	8.3
Years of service rendered.....		11.7	11.0
Acres covered during life.....		48.0	91.3
Days actually used during life.....		10	9
Size of implement.....		1-row.	2-row.
Cost when new.....		\$12.00	\$40.00
Total cost of repairs during life.....		8.07	18.48
Total interest during life at 6 per cent.....		5.38	12.41
Total of depreciation, interest, and repairs during life.....		25.45	70.89
Cost of corn planter:			
Per day used.....		\$2.55	\$7.89
Per acre planted.....		.53	.79

THE ONE-HORSE CULTIVATOR.

The average 1-horse cultivator lasts 14 years and does 58 days of work (Table X). The farmer who cultivates annually 60 acres, as compared with the man who cultivates only 7, obtains over five times as much acreage and days of use from a similar implement.

Although the larger acreages are cultivated by the more expensive and better implements the machines working the smaller acreages annually are, nevertheless, the more expensive per acre. The average depreciation charge was found to be \$0.027 per acre and the interest charge, at 6 per cent, is \$0.012 per acre.

TABLE X.—*One-horse cultivators—relation of work done annually to service and cost per acre and per day used on 926 farms.*

Range of area covered annually.....	acres.....	1 to 10.	11 to 20.	21 to 40.	41 and over.	Average.
Number of records included.....		476	352	27	71	.....
Average area covered annually.....	acres.....	6.8	15.4	28.2	57.9	16.9
Years of service rendered.....		15.2	14.7	12.8	9.6	14.0
Acres covered during life.....		103.4	226.4	361.0	555.8	236.6
Days actually used during life.....		25	56	89	137	58
Cost when new.....		\$6.00	\$6.50	\$7.25	\$8.50	\$6.50
Total cost of repairs during life.....		3.80	5.88	5.37	5.47	4.90
Total interest during life at 6 per cent.....		2.89	3.09	3.07	2.69	2.94
Total of depreciation, interest, and repairs during life.....		12.69	15.47	15.69	16.66	14.34
Cost of 1-horse cultivator:						
Per day used.....		\$0.507	\$0.276	\$0.176	\$0.121	\$0.247
Per acre cultivated.....		.123	.068	.043	.029	.060

The average repairs for 1-horse cultivators amount to \$4.90 during their entire life, or about 75 per cent of the first cost of the implement. The average repair charge per acre is \$0.021 and per day \$0.085.

THE RIDING CULTIVATOR.

The riding cultivators used in this section (Table XI) last an average of 12.5 years, doing 491 acres or 70 days of work. A cultivator that covers 15 acres annually lasts only three years longer than one that cultivates 125 acres annually, being used in all less than one-sixth as many days. Rust and decay appear to exact a heavy toll of the man with limited use for his cultivator.

From the computations for riding cultivators it appears that the overhead charges per acre are more than twice those for the walking cultivator, the depreciation charge averaging \$0.065 per acre and the interest charge \$0.027. But to cover a given acre with a 1-horse cultivator requires nearly twice as many man hours as it does to cultivate the same area with a 2-horse implement. Where wages are low, especially if the area to be cultivated is small, the 1-horse implement is more economical; but where wages are high and the area large, it is cheaper to use a 2-horse implement.

TABLE XI.—*Riding cultivators—relation of work done annually to service and cost per acre and per day used on 881 farms.*

Range of area covered annually.....acres..	1 to 20.	21 to 40.	41 to 80.	81 and over.	Average.
Number of records included.....	321	294	190	76	.....
Average area covered annually.....acres..	14.7	31.6	58.3	124.8	39.3
Years of service rendered.....	13.7	12.8	11.4	10.7	12.5
Acres covered during life.....	201.4	404.5	664.6	1,335.4	491.3
Days actually used during life.....	28	57	93	186	70
Cost when new.....	\$30.00	\$32.00	\$35.00	\$36.00	\$32.00
Total cost of repairs during life.....	8.91	12.67	13.34	21.72	12.38
Total interest during life at 6 per cent.....	13.29	13.31	13.00	12.63	13.00
Total of depreciation, interest, and repairs during life.....	52.20	57.98	61.34	70.35	57.38
Cost of riding cultivator:					
Per day used.....	\$1.87	\$1.02	\$0.66	\$0.38	\$0.82
Per acre cultivated.....	.259	.143	.092	.057	.117

The average cost of repairs per acre for riding cultivators is \$0.025, only a little more than for the walking type. The total repairs during the life of the average riding cultivator amount to about 40 per cent of its first cost.

THE CABBAGE TRANSPLANTER.

Cabbage transplanters, setting an average of 12.5 acres annually, last nearly 13 years, doing 43 days of actual work (Table XII). Farmers having the larger areas to plant obtain much greater acreages and days of work from their transplanters. These highly specialized planting machines could well be owned on shares, so that the implement cost per acre might be reduced by planting more acres annually.

TABLE XII.—*Cabbage transplanters—relation of work done annually to service and cost per acre and per day used on 217 farms.*

Range of area covered annually.....acres..	1 to 10.	11 and over.	Average.
Number of records included.....	139	78	.....
Average area covered annually.....acres..	6.2	23.8	12.5
Years of service rendered.....	13.2	11.9	12.8
Acres covered during life.....	81.8	283.2	160.0
Days actually used during life.....	22	77	43
Cost when new.....	\$45.00	\$45.00	\$45.00
Total cost of repairs during life.....	11.74	18.55	14.46
Total interest during life at 6 per cent.....	19.14	17.37	18.56
Total of depreciation, interest, and repairs during life.....	75.88	80.93	78.02
Cost of cabbage transplanter:			
Per day used.....	\$3.45	\$1.05	\$1.81
Per acre set.....	.927	.285	.437

For the use of a transplanter costing \$45 there are charges for replacement and interest averaging \$0.28 per acre for depreciation and \$0.114 per acre for interest at 6 per cent.

The repairs on cabbage transplanters average \$0.091 per acre or \$0.336 per day used. The average transplanter costs about \$45 and the repairs necessary during its life amount to about 36 per cent of the original outlay for the machine.

ENGINE SPRAYER.

The average cost of repairs for gasoline-engine-operated spraying outfits is \$0.27 per day (Table XIII). The number of trees per acre is so variable that it is most convenient to consider repair charges on the basis of the tree rather than the acre.

TABLE XIII.—*Cost of repairs for gasoline-engine-driven power sprayers in western New York.*

Days used annually.		Cost of repairs.		Number reporting.
Range.	Average.	Per sprayer annually.	Per day used.	
1 to 5.....	3.9	\$1.05	\$0.27	41
6 to 10.....	9.0	3.35	.37	140
11 to 15.....	13.6	5.06	.37	71
16 to 20.....	19.2	5.44	.28	52
21 and over...	37.6	5.85	.16	55
Average....	15.2	4.11	.27	359

The average number of trees that can be sprayed in a day with a gasoline-engine outfit is about 220, the trees having an average height and spread of 18 to 20 feet. The average repair cost per tree amounts

to about one-eighth of 1 cent. The average cost per tree for trees of different height ¹ is approximately as follows:

Height of tree.	Cost per tree.
12 feet or less.....	\$0.0008
13 to 20 feet.....	.0015
21 feet and over.....	.0021
Average.....	.0012

The cost per acre depends upon the number of trees planted per acre, and can readily be computed for any given orchard by multiplying the appropriate one of the above amounts by the number of trees per acre.

MOWERS.

While the mower is a machine with rapidly reciprocating parts, it gives relatively long service. Inspection of Table XIV indicates that the average farmer does not obtain the maximum days of work from his mower. Mowers that cut 14 acres annually last only four years longer than machines that cut 90 acres a year, the latter doing 100 days of work against 25 for the former. The size of the mower has some influence on the total acres cut by mowers before wearing out, but the principal contributing factor to a high record of days of work appears to be large acreage annually.

TABLE XIV.—*Mowers—relation of work done annually to service and cost per acre and per day used on 1,232 farms.*

Range of area covered annually.....acres..	1 to 15.	16 to 30.	31 to 45.	46 to 60.	61 and over.	Average.
Number of records included.....	368	518	193	110	43	.....
Average area covered annually.....acres..	13.8	23.6	38.8	53.6	88.8	28.0
Years of service rendered.....	16.1	14.3	14.6	13.1	11.9	14.3
Acres covered during life.....	222.2	337.5	566.5	702.2	1,056.7	414.4
Days actually used during life.....	25	38	60	70	100	46
Average width of mower.....feet.....	4.9	5.0	5.4	6.0	6.4	5.2
Cost when new.....	\$10.00	\$10.00	\$12.00	\$15.00	\$17.50	\$11.00
Total cost of repairs during life.....	19.00	24.45	35.77	37.47	37.84	26.94
Total interest during life, at 6 per cent.....	20.45	18.30	19.71	19.00	18.33	19.39
Total of depreciation, interest, and repairs during life.....	79.45	82.75	97.48	101.47	103.67	87.33
Cost of mower:						
Per day used.....	\$3.18	\$2.18	\$1.62	\$1.45	\$1.04	\$1.90
Per acre mowed.....	.357	.245	.172	.144	.098	.210

The overhead charges against mowers doing the amount of annual work shown in Table XIV average \$0.099 for depreciation and \$0.047 for interest per acre.

¹ Computed from Table XXVI, U. S. Dept. of Agr. Bul. No. 3.

The mower requires repairs amounting to \$0.065 per acre, or \$0.60 per day used. The total repairs necessary during the life of the average mower amount to \$26.94, or about 66 per cent of the cost of a new mower at \$41.

THE HAY RAKE.

From the standpoint of shelter when not in use, the hay rake (Table XV) is probably the most abused implement on the farm. It is a tool which covers large acreages in a day, so that its low record of actual days of work is offset by a low overhead cost per acre and per ton. The average 10-foot rake in this section lasts 14.5 years in doing 37 days of work, and raking 623 acres of hay.

Against hay rakes in western New York costing an average of \$24, the average depreciation charge per acre is \$0.038 and the interest charge \$0.019. These overhead charges become steadily less as the acreage raked annually is increased.

TABLE XV.—*Hay rakes—relation of work done annually to service and cost per acre and per day used on 1,217 farms.*

Range of area covered annually .....acres..	1 to 25.	26 to 50.	51 and over.	Average.
Number of records included.....	402	525	290	-----
Average area covered annually.....acres..	17.8	39.1	84.9	43.0
Years of service rendered.....	13.0	15.6	13.8	14.5
Acres covered during life.....	231.4	610.0	1,171.6	623.5
Days actually used during life.....	16	36	67	37
Average width of rake.....feet..	8.6	9.9	11.4	9.8
Cost when new.....	\$22.00	\$24.00	\$26.00	\$24.00
Total cost of repairs during life.....	3.64	5.93	6.07	5.22
Total interest during life, at 6 per cent.....	9.23	12.01	11.49	11.17
Total of depreciation, interest, and repairs during life.....	34.87	41.94	43.56	40.39
Cost of hay rake:				
Per day used.....	\$2.19	\$1.17	\$0.65	\$1.09
Per acre raked.....	.151	.062	.037	.065

The hay rake is used without heavy repair charges, the average being only \$0.008 per acre, or \$0.141 per day used. The total repairs during its life are only \$5.22, or about 22 per cent of its original cost.

THE HAY TEDDER.

The hay tedder is an implement that must be kept on hand by growers of considerable acreages of hay, but in some seasons it is not used much. Of the 416 tedders reported in Table XVI, the average service is 14 years, out of which only 21 days' use of the tedder is obtained.

The overhead charges per acre on hay tedders average \$0.112 for depreciation and \$0.051 for interest.

TABLE XVI.—*Hay tedders—relation of work done annually to service and cost per acre and per day used on 416 farms.*

Range of area covered annually	1 to 15.	16 to 30.	31 and over.	Average.
Number of records included.....	174	190	52	.....
Average area covered annually.....acres..	9.9	23.9	52.2	21.6
Years of service rendered.....	14.8	13.8	12.6	14.0
Acres covered during life.....	146.5	329.8	657.7	302.4
Days actually used during life.....	10	23	46	21
Cost when new.....	\$32.00	\$35.00	\$35.00	\$34.00
Total cost of repairs during life.....	3.85	7.04	6.68	5.74
Total interest during life, at 6 per cent.....	15.10	15.69	14.24	15.26
Total of depreciation, interest, and repairs during life.....	50.95	57.73	55.92	55.00
Cost of hay tedder:				
Per day used.....	\$5.10	\$2.51	\$1.21	\$2.61
Per acre tugged.....	.348	.175	.085	.181

The annual repairs for a hay tedder average only \$0.41, the cost per acre being \$0.019. The hay tedder is used only a few days in the season. The repair cost per day amounts to \$0.273. The average first cost of a hay tedder is about \$34, so that the total repairs needed during its life on the farm are only 17 per cent of the original cost of the implement.

THE BEAN HARVESTER.

The bean harvester used in western New York is an implement with no moving parts, and lasts about 13 years, of which 29 days are spent in actual work harvesting 218 acres. If wheel bearings are properly lubricated and the knives kept repaired or replaced as they wear, these machines should last almost indefinitely. The data of Table XVII indicates that the amount of work done up to 45 days has little effect on the life of the harvesters.

TABLE XVII.—*Bean harvesters—relation of work done annually to service and cost per acre and per day used on 563 farms.*

Range of area covered annually	1 to 10.	11 to 20.	21 to 30.	Average.
Number of records included.....	168	266	129	.....
Average areas covered annually.....acres..	8.5	17.1	27.6	16.9
Years of service rendered.....	13.7	12.5	12.7	12.9
Acres covered during life.....	116.4	213.8	350.5	218.0
Days actually used during life.....	15	28	46	29
Cost when new.....	\$25.00	\$25.00	\$25.00	\$25.00
Total cost of repairs during life.....	8.63	12.50	19.81	13.03
Total interest during life, at 6 per cent.....	11.10	10.13	10.16	10.32
Total depreciation, interest, and repairs during life.....	44.73	48.03	54.97	48.35
Cost of bean harvester:				
Per day used.....	\$2.98	\$1.71	\$1.19	\$1.67
Per acre harvested.....	.384	.224	.156	.221

On bean harvesters the average depreciation charge per acre is \$0.115 and the interest charge \$0.048.

The cost of repairs for the bean harvester averages \$0.06 per acre, \$0.449 per day used, and \$13.03 for its entire life on the farm, or about 60 per cent of its first cost.

THE GRAIN BINDER.

Although a grain binder is a large and complicated machine, with many revolving and reciprocating parts, it lasts an average of over 15 years in western New York in cutting 542 acres, but does only 53 days of actual work (Table XVIII). As in the case of other implements, the smaller binders last longer in years but do less work in days and acres than the larger machines.

TABLE XVIII.—*Grain binders—relation of work done annually to service and cost per acre and per day used on 1,028 farms.*

Range of area covered annually .....acres..	1 to 20.	21 to 40.	41 to 60.	61 and over.	Average.
Number of records included.....	274	494	191	69	.....
Average areas covered annually.....acres..	15.5	32.5	52.8	85.0	35.2
Years of service rendered.....	17.8	14.4	14.2	13.6	15.4
Acres covered during life.....	275.9	468.0	749.8	1,156.0	542.1
Days actually used during life.....	27	45	92	103	53
Average width of binder.....feet..	5.6	6.0	6.1	7.1	6.0
Cost when new.....	\$125.00	\$125.00	\$130.00	\$135.00	\$125.00
Total cost of repairs during life.....	24.92	26.50	39.05	54.67	31.20
Total interest during life at 6 per cent.....	70.49	57.74	59.21	59.16	61.60
Total of depreciation, interest, and repairs during life.....	220.41	209.24	228.26	248.83	218.02
Cost of grain binder:					
Per day used.....	\$8.15	\$4.47	\$3.17	\$2.42	\$4.11
Per acre cut.....	.80	.447	.304	.215	.402

For grain binders the depreciation and interest charges average \$0.231 and \$0.113 per acre, respectively. A binder that cuts 16 acres annually costs about $3\frac{1}{2}$ times as much per acre as one that cuts 70 acres a year. As the acreage cut increases the interest charge becomes a smaller proportion of the total overhead charge, as is the case with the other implements.

It costs nearly 60 cents a day of use to keep a grain binder in repair, or \$0.058 per acre cut. Before a binder is worn out 25 per cent of its first cost, on the average, must be spent to keep it in running order.

THE CORN BINDER.

From Table XIX it appears that the corn binder is not in such common use as are the grain binder, mower, and other standard machines in this section. The average corn binder does only 40 days of actual work, and there is no doubt but that it could render several times this much service before wearing out.

TABLE XIX.—*Corn binders—relation of work done annually to service and cost per acre and per day used on 458 farms.*

Range of area covered annually	acres..	1 to 15.	16 and over.	Average.
Number of records included		233	225	.....
Average area covered annually	acres..	10.1	32.5	21.2
Years of service rendered		11.0	10.6	10.8
Acres covered during life		111.1	344.5	227.9
Days actually used during life		19	60	40
Cost when new		\$125.00	\$125.00	\$125.00
Total cost of repairs during life		15.73	28.20	21.92
Total interest during life at 6 per cent		45.00	42.46	43.28
Total of depreciation, interest, and repairs during life		185.73	195.66	190.20
Cost of corn binder:				
Per day used		\$9.78	\$3.24	\$4.76
Per acre cut		1.67	.568	.83

The replacement cost averages \$0.55 per acre and the interest charge at 6 per cent is \$0.194 per care.

The corn binder requires an expenditure of \$0.096 per acre for repairs, or about \$0.50 for each day used. About 17½ per cent must be added to its original cost for repairs during its life.

RELATION OF ANNUAL REPAIRS TO FIRST COST.

In making farm plans for the years to come, it is often desirable to know what the normal relation is between the first cost of an implement and the annual repairs which must be provided for. Table XX has been prepared for the purpose of affording data of this character for the implements discussed in this bulletin. The sizes of implements shown in the first column of the table are the same as the averages for the corresponding implements in Tables II to XIX.

The first cost in the second column is taken from farm inventories recorded in the western New York area. The third column of the table shows the percentage of the first cost that must, on the average, be laid out annually for repairs for each implement.

The fourth column is the average present value of the respective implements that would be obtained by making an inventory valuation and computing the average.¹ The fifth column shows the percentage of the present value that must be laid out for repairs annually to keep each machine in running order.

¹ The fourth column of the table represents the average investment upon which the farmer must earn interest at the borrowing rate in his locality where he charges off for depreciation annually a part of the first cost in proportion to the average life of his respective implements. This average investment is identical with the average present value that would be obtained by making an inventory valuation of the same implements and computing the average. The relation of first cost to average farm value of machinery in use is shown on page 5 for equipment having average life ranging from 1 to 20 years.

TABLE XX.—*Relation of the annual outlay for repairs to the first cost and present value of farm implements in western New York.*

Implement.	Average size.	First cost.	Per cent of first cost expended annually for repairs.	Average present value.	Per cent of present value expended annually for repairs.
Walking plow.....	11.8 inches.	\$10.00	20.5	\$5.43	37.8
Sulky plow.....	13.3 inches.	42.50	5.0	23.88	8.9
Spring-tooth harrow.....	6.9 feet.	17.50	4.3	9.54	7.9
Spike-tooth harrow.....	11 feet.	17.00	2.0	9.01	3.8
Disk harrow.....	6.4 feet.	27.00	1.8	14.54	3.4
Land roller.....	8.1 feet.	24.00	2.0	12.75	3.8
Grain drill.....	6.2 feet.	72.00	1.8	38.19	3.3
Corn planter.....	1-row.....	12.00	5.8	6.51	10.6
Do.....	2-row.....	40.00	4.2	21.82	7.7
1-horse cultivator.....	.....	6.50	5.4	3.48	10.0
Riding cultivator.....	.....	32.00	3.1	17.28	5.7
Cabbage setter.....	.....	45.00	2.5	24.26	4.7
Mower.....	5.2 feet.	41.00	4.4	21.89	8.3
Hay rake.....	9.8 feet.	24.00	1.5	12.83	2.8
Hay tedder.....	.....	34.00	1.2	18.31	2.2
Bean harvester.....	.....	25.00	4.0	13.47	7.5
Grain binder.....	6 feet.	125.00	1.6	66.56	3.1
Corn binder.....	.....	125.00	1.6	69.54	2.9

From Table XX it appears that the walking plow is the only implement that requires much over 5 per cent of its first cost to be expended annually for repairs; corn planters are so little used here that the data for these implements, showing 5 per cent annually, may be only approximately correct.

Tabulation of the repair expense according to the age of the implements showed no uniform increase in repair cost as the age increased, the repairs being low the first year or two and practically the same per year thereafter.

SHELTER.

Much has been written and said about the waste incurred by lack of housing for machinery on farms. Many large and successful farmers do not shelter their machinery at all. The principle which guides them is that if a machine not housed at all will wear out before it is injured by exposure there is no need to shelter it. The larger the amount of work that can be done with an implement annually, therefore, the less need there is to house it. The waste, by depreciation, of capital invested in farm machinery is caused primarily by the inability of the smaller farms to wear out their implements with profitable use. An economic remedy is partial reorganization of their business and cooperation with neighbors so that more work can be done annually with the machinery equipment.

There are no data available on the relative life of machinery when housed and when not housed. Careful study of the cost of housing farm machinery in an area in eastern New York indicated that farmers do not invest in special machinery shelter to a greater extent than 20 per cent of the first cost of their implements. Similar data from eastern Nebraska gave a percentage of 10 or less, the relative

amount decreasing as the size of farm increased. The greater humidity in New York makes more urgent the shelter of implements while the larger areas farmed in Nebraska makes such shelter less economical. The more substantial methods of construction in New York also add to the greater relative cost. As previously noted, except during a period in summer when the general buildings are filled with crops, there is usually ample space available for housing most of the farm machinery on farms in western New York. It would seem that an investment in special implement sheds amounting to over 15 per cent of the total cost of farm machinery would indicate poor management in utilizing available space in the general farm buildings for the purpose of housing such machinery.

The walking plow, disk harrow, land roller, 1-row cultivator, hay-rake, and hay tedder are among the more expensive implements to house in proportion to their cost. They constitute the group most frequently not housed. It happens that, being made of heavy wooden or metal parts with few moving elements, they are less injured by exposure than are some others. They can endure considerable exposure when barns are filled with crops, and are more economically stored at other times in general-purpose space. Machines such as binders, mowers, drills, planters, etc., having many moving parts, or many of light metal or wood, are seriously affected in operation by rust and decay and are in greater need of protection from the weather, hence they are the first to be housed in this and other sections. Their form renders them economical to house from the standpoint of relative cost of machine and shelter. It is ordinarily profitable to provide special shelter for these machines. There is no way, however, by which the small farmer can escape a greater shelter charge per acre than that enjoyed by the large farmer.

RELATION OF MACHINERY COST TO COST OF FARM OPERATIONS.

The most urgent reason for investment in machine sheds, farm repair shops, and repair tools is that machinery will then be more readily and certainly repaired and kept in running order, so that it will not fail during busy seasons and waste the more expensive time of men and horses.

In Table XXI the relation of the cost of machinery to the total cost of the various farm operations with these implements has been computed and expressed in percentages. In arriving at these percentages, the general averages were taken from Tables II to XIX, respectively, as being the average cost to the farmers in western New York. Man time was taken at \$2 per day for wages and board, with all implements except those used in haying and in grain harvest, the wages for these being placed at \$3.25 per day for wages and board. Horse time was entered at 75 cents per day per horse to cover feed, interest, depreciation, and mortality.

TABLE XXI.—*Relation of machinery cost to the total cost of farm operations in western New York.*

Operation.	Men.	Horses.	Per cent of cost contributed by the implements.	Operation.	Men.	Horses.	Per cent of cost contributed by the implements.
Plowing (walking).....	1	2	4.7	Cultivating.....	1	1	8.2
Plowing (sulky).....	1	3	12.6	Do.....	1	2	19.1
Harrowing (spring tooth).....	1	2	11.2	Transplanting cabbage... 3	2		19.4
Harrowing (spike tooth).....	1	2	11.7	Mowing hay.....	1	2	28.7
Harrowing (disk).....	1	2	19.2	Raking hay.....	1	2	18.7
Rolling.....	1	2	14.0	Tedding hay.....	1	2	35.6
Drilling grain.....	1	2	32.8	Harvesting beans.....	1	2	32.3
Planting corn.....	1	1	48.0	Harvesting grain (binder)	1	2	42.8
Do.....	1	2	69.9	Harvesting corn (binder) .	1	3	52.7

With the exception of corn planters and corn binders, which are used only a day or two annually, the machinery cost of the various operations does not exceed 50 per cent of the whole, while for the standard farm operations the machinery cost ranges from 4.7 per cent for the walking plow to 42.8 per cent for the grain binder. These percentages represent the average of conditions in western New York. The larger farms enjoy a much lower percentage of machinery cost and those smaller than the average labor under much heavier charges. Where larger numbers of horses are used the machinery cost is, of course, relatively less.

It appears to be more economical to keep the machinery cost of farm operations down by management that will secure a maximum number of days of profitable service from each implement annually than to spend money to shelter idle machinery. It is still more important to keep men and horses profitably engaged the maximum number of days in the year, since these are much more expensive than the machinery, both in daily cost while working and, in the case of horses, in depreciation, interest, and maintenance charges while not working.

CONCLUSION.

The averages of the foregoing tables represent the normal repair cost for the respective implements doing the annual amounts of work indicated. The data thus made available are of permanent utility in arriving at the cost of farm enterprises where these machines are used.

The replacement and interest charges computed for the respective implements in this bulletin will serve as a basis for computing the proper overhead charges for machinery at other prices and interest rates and doing the same amount of annual work, by the simple operation of applying proportion to the averages given here. For the conditions in western New York the overhead charges as computed are basic in character, and will be of service in determining the cost of work done or to be done on the farm, in deciding whether to buy or rent farm machinery, and in solving countless other problems in farm management and organization.

UNITED STATES DEPARTMENT OF AGRICULTURE



BULLETIN No. 339

Contribution from Office of Public Roads and Rural Engineering
LOGAN WALLER PAGE, Director



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PROFESSIONAL PAPER

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EXPERIMENTS ON THE ECONOMICAL USE OF IRRIGATION WATER IN IDAHO.

By DON H. BARK, *Irrigation Engineer.*

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Plan of investigation.....	2	under complete canal systems.....	43
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INTRODUCTION.

This bulletin contains the results of experiments made in cooperation with the State Land Board of Idaho to determine the quantities of water needed to produce the ordinary farm crops on the types of soil common to that State. The experiments, in addition to investigations strictly bearing on such irrigation requirements, included certain supplementary investigations.

The irrigation-requirement experiments extended from 1910 through 1913 and consisted in applying different quantities of water to plots receiving similar treatment except for this factor. It is considered that these experiments fix within reasonable limits the amount of water which must be delivered to fields to produce profitable crops under the conditions described. The supplementary experiments were made for the purpose of determining how much additional water must be allotted to cover waste and losses between the point of diversion and the fields to be irrigated.

The conclusions contain a discussion of the factors affecting irrigation requirements in actual practice.

NOTE.—The work on which this bulletin is based was done under a cooperative agreement between the Office of Experiment Stations and the State Land Board of Idaho, several of the canal companies and the railway companies operating in Idaho contributing to the expense of the work. The bulletin will be of interest to officials administering the water supply of the Western States, to students of irrigation practice, and to farmers.

PLAN OF INVESTIGATION.

The investigation was planned to show the actual irrigation requirements of the various soils and crops common to southern Idaho. The staple crops—alfalfa, clover, pasture, spring and winter grains, potatoes, and orchards—have all been represented. The fields had a varying topography, with slopes ranging from 20 feet in 100 to 4 feet per mile.

In order to make the results practical and dependable and such as good farmers might obtain under average conditions it was decided: (1) That the investigation must be conducted in the main by men employed especially for the purpose and without outside interests; (2) that the areas experimented upon must be comparatively large; (3) that the investigation must extend over several years, so as to eliminate or neutralize the individual characteristics of the different seasons; and (4) that the mere measurement of the water applied to single tracts would be insufficient, for this would not show the yield that might have been produced by a greater or lesser application of water.

SCOPE OF INVESTIGATION.

As mentioned above, the study extended through four seasons, during which time water was measured upon 529 individual tracts, having a total area of slightly over 3,600 acres. In order to determine the normal quantity used by the farmers when such use was unrestricted and not influenced in any way by the proximity of experiments, the water applied by them to 28 other tracts, having a total area of 1,306.8 acres, was measured with automatic water registers.

The water diverted and used by seven different canal systems in 1911 and nine systems in 1912 was measured, and the areas irrigated under them were determined.

In a comprehensive study of the transmission losses of canals the seepage losses in 118 sections of different canals with an aggregate length of 278.3 miles were determined. The canals measured varied in discharge from 0.07 to over 3,190 cubic feet per second, and in cross section from 0.117 to 984 square feet.

The percentage of nonirrigated or waste land in a typical project was also determined, 16,067.8 acres located in two bodies being surveyed for the purpose.

The territory covered extends from Rigby, with an altitude of 4,950 feet, in the upper Snake River Valley, to Weiser, with an altitude of 2,114 feet, on the western boundary of Idaho, a distance of 368 miles.

SELECTION OF TRACTS.

As it was imperative that the final results of the investigation should show a duty that could be secured by good average farmers without more expensive preparation than would be justified, only such tracts as were considered typical in regard to soil and practical in regard to preparation were included, and they were not especially prepared for the investigation in any way.

DIVISION OF TRACTS AND VARIATION OF WATER.

Each tract selected, wherever its topography and size permitted, was divided into three approximately equal parts, care being taken to select only such tracts as had uniform soil conditions and previous preparation and cropping throughout, in order that the results from the different plots might be strictly comparable. In most cases the tracts consisted of about 15 acres, divided into three plots of about 5 acres each, in the same crop on the same soil, with all conditions uniform, except that a different volume of water was applied to each plot.

Weirs were installed in the ditches leading to and from each tract in order to measure the water applied and wasted. These tracts were selected from average irrigators' farms in representative districts, and the owner of each was allowed to select one of the plots into which his tract had been divided and to irrigate and handle it during the season and apply the water at such times as had been his usual custom. The two remaining plots were irrigated by applying more water to one and less to the other than the owner applied to the plot he himself had selected. The yield produced usually indicated which plot had received the supply of water best suited to the soil and crop in question. Usually four or five experimental tracts were selected from as many farms in the same neighborhood, since one assistant could look after and irrigate that number of tracts provided the same were located within a radius of 2 or 3 miles. The water wasted from each tract was measured, and all amounts tabulated in this report unless otherwise specified represent only the quantities retained upon the land.

MEASUREMENT OF WATER.

Cipolletti weirs were used in the measurements, the weir boxes usually being built of 1-inch lumber. The weir plates used were 16-gage galvanized iron. The head on the weirs was measured each hour or oftener, as was required, with small steel rules graduated to 0.01 foot. Measurements of the head were made from the tops of spikes driven vertically into substantial 2 by 4 or 4 by 4 stakes placed in the weir pools upstream from the weirs, at about twice their length.

The spikes in the tops of the stakes were leveled with the weir crests by means of long carpenter's levels, great care being exercised to keep them level at all times. It was found that excess velocity of approach, due to the filling up of the weir pools, was the most frequent source of error in weir measurements, and special care was taken throughout the entire investigation to maintain weir pools of sufficient size and depth to insure a slow velocity of approach. The formula used in computing the discharge over the weirs was $Q = 3.367 L H^{\frac{3}{2}}$, where Q = discharge in cubic feet per second, L = length of crest in feet, and H = head or depth of water on the crest in feet.

Usually the head was measured every hour, but where the flow remained rather constant measurements sometimes were taken at two-hour intervals, and where much fluctuation occurred the head was measured oftener than every hour. Plate I, figures 1 and 2, should furnish a clear idea of the type of weirs used. The volume of water diverted by the large projects was determined by daily gage readings and current-meter determinations.

DETERMINATION OF AREAS AND YIELDS.

With the exception of the large projects, all areas included in this investigation have been determined by transit and chain surveys. The transit notes were plotted on a scale of 100 feet to the inch, and the acreage was determined from the map with a polar planimeter. It is believed that the areas of all of the tracts in this variation experiment have been determined within 0.01 acre.

The crops from the three plots into which each tract has been divided have invariably been cut, stacked, and thrashed separately, and weighed wherever possible. In cases where grain or alfalfa fields were located at long distances from a set of wagon scales and weighing has been impracticable, the yields from the different plots have been determined by the automatic weighers attached to the thrashing machines and by the measurement of the hay in the stack. While the determination of the yields by the latter method has not been absolutely accurate, the same method has been used with all plots into which a tract was divided, thus insuring comparable results.

CLASSIFICATION OF SOIL.

The soils on the different tracts have been classified with respect to their mechanical composition only, chemical analyses having been made in but few cases. Representative samples of the first, second, third, and fourth foot of soil from each tract experimented upon have been secured and prepared and are now filed away for further reference. The soils varied from the finest of adobe clays to the coarsest gravels. The extremes of soil which have been included



FIG. 1.—UPSTREAM VIEW OF CIPOLLETTI WEIR USED IN THE IDAHO INVESTIGATION.



FIG. 2.—DOWNSTREAM VIEW OF CIPOLLETTI WEIR USED IN IDAHO INVESTIGATION, SHOWING METHOD OF MEASURING.

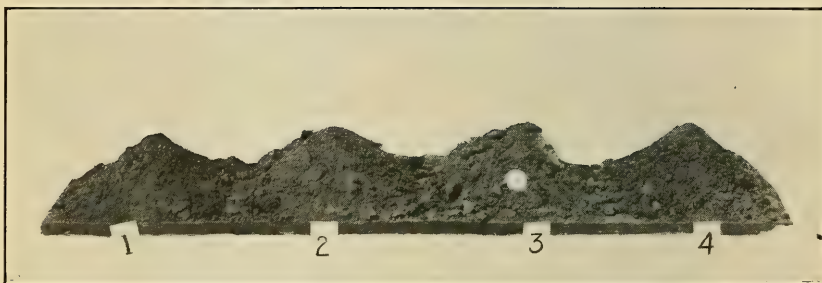


FIG. 1.—SAMPLES OF FIRST, SECOND, THIRD, AND FOURTH FOOT OF CLAY LOAM SOIL OF FINE UNIFORM TEXTURE.

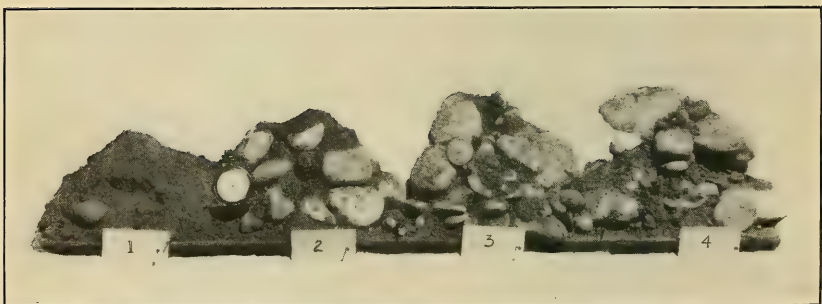


FIG. 2.—SAMPLES OF FIRST, SECOND, THIRD, AND FOURTH FOOT OF VERY GRAVELLY SOIL.

are well represented in Plate II, figures 1 and 2, which show the average soil of the first, second, third, and fourth foot of two of the experimental tracts.

MOISTURE DETERMINATIONS.

The primary object of this investigation having been to determine the quantity of irrigation water required by the soils and crops of a farm or project, it was not considered advisable or practical on account of the large territory involved to go to the expense of making exhaustive soil-moisture determinations on all tracts throughout the season. A careful determination of the moisture in the first, second, third, and fourth foot of soil of each plot experimented upon was made, however, before the first irrigation and about the time plants started to grow in the spring. This was done by securing a large number of representative samples from each tract and drying them in an oven at a temperature of 108° C. While the available soil moisture has not been taken into consideration in averaging the quantities of water used and the yields obtained, these determinations have permitted of a careful comparison of the results secured from the different experiments.

REIMBURSEMENT OF LOSSES.

The owners of the various experimental tracts included in the investigation have been reimbursed for all crop losses that have been experienced because of variation of the water supply. The yield of the plot selected and handled by the owner himself was used in each case as a basis for determining the loss. Reimbursement was found necessary in connection with less than one-third of the tracts included in the investigation.

METHOD OF INTERPRETING RESULTS.

The correct and proper analysis of the results has been the most difficult part of the entire investigation. Even when the greatest care is used in agricultural experiments there are many factors other than those under observation which may influence the yields. Normally it has been assumed that the plot which produced the best yield in each experiment received the best application of water. In many cases, however, the largest yield has exceeded the yield of one of the other plots by not more than 2 to 5 per cent, when the quantity of water applied for the maximum yield exceeded that applied to the next largest yield by as much as 100 per cent. In such cases it is apparent that if economy of time and water is to be considered, it is better practice to apply the smaller quantity of water. The investigation as a whole has emphasized the fact that the results from single experiments can not be depended upon,

because there have sometimes been great variations in the yields produced by the same quantity of water on the same crop upon adjoining farms. These variations have made it very evident that dependable results can be secured from agricultural experiments only by basing conclusions upon the average of results from a large number of experiments.

WEATHER CONDITIONS IN IDAHO DURING THE INVESTIGATION.

It has not been considered practicable, although it would have been desirable, to install a rain gage in connection with each tract

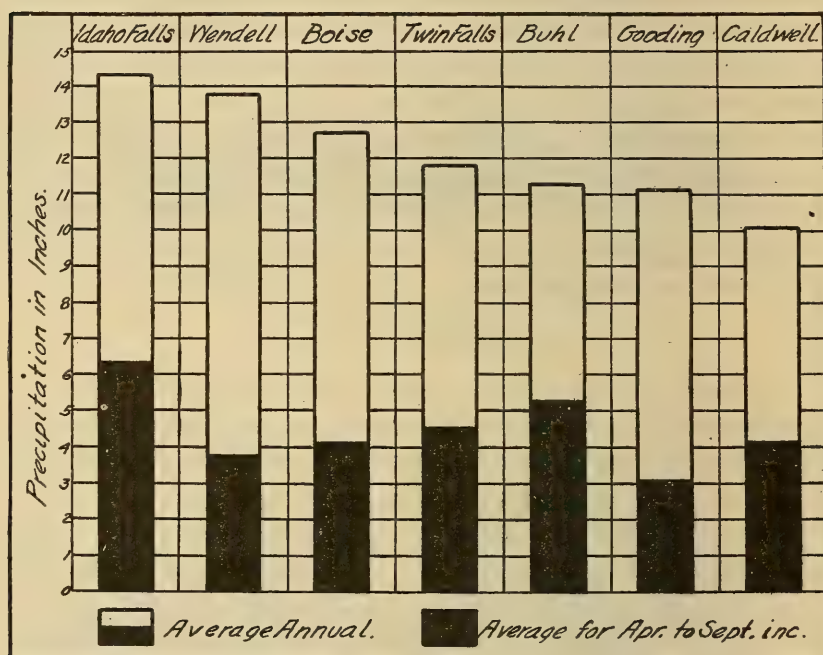


FIG. 1.—Comparison of average annual precipitation with that occurring during the growing season.

experimented upon. The United States Weather Bureau has a large number of cooperative observers' stations scattered quite uniformly throughout the territory involved in the investigation, and the precipitation recorded at the station nearest each tract has been used. This may be slightly inaccurate, but the errors are compensating and small at the most.

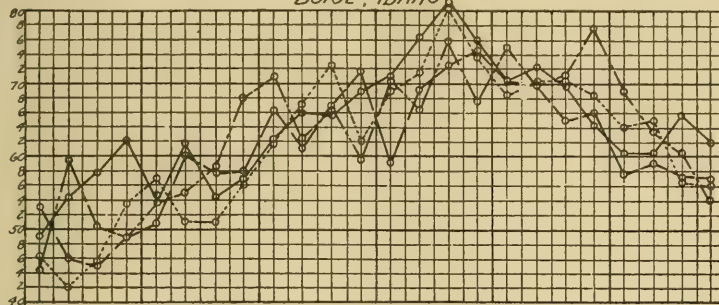
The normal annual precipitation in the districts of southern Idaho which have been investigated ranges from slightly less than 10 inches per annum at Oakley to 17.75 inches at Hailey. Hailey is situated at a comparatively high altitude, and the precipitation in this place is consequently above the average for irrigated southern Idaho. The average precipitation in the typical irrigated districts

MEAN WEEKLY TEMPERATURE 1910-1913.

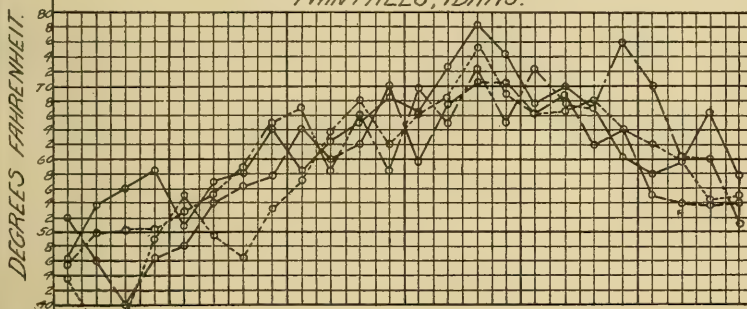
 1910 —————
 1911 - - - - -

 1912 —————
 1913 - - - - -

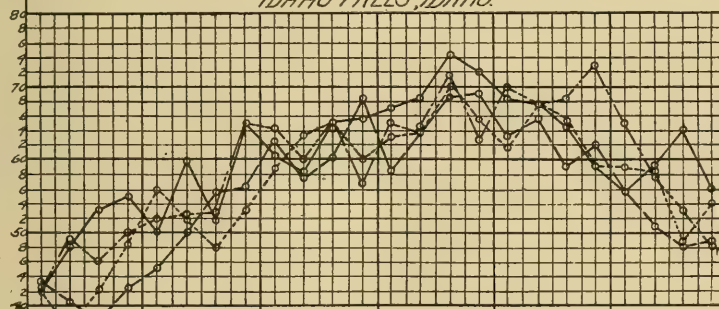
BOISE, IDAHO



TWIN FALLS, IDAHO.



IDAHO FALLS, IDAHO.



APRIL. MAY. JUNE. JULY. AUGUST. SEPTEMBER.

1st week	2nd "	3rd "	4th "	1st week	2nd "	3rd "	4th "	1st week	2nd "	3rd "	4th "	1st week	2nd "	3rd "	4th "	1st week	2nd "	3rd "	4th "
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FIG. 2.—Range of temperature during the growing season for three representative districts.

ranges from about 10 to 14 inches per annum, of which from as low as 3 inches to as high as 6.7 inches, or about one-third, occur during the growing season from April to September, inclusive.

The growing season of 1910 in Idaho was the driest on record. The precipitation during seven consecutive months, from March to September, inclusive, was below normal, but the temperature ranged above normal during the entire season. The seasons of 1911 and 1912 averaged much cooler than that of 1910, but the precipitation during both of these years ranged above normal during the entire growing season, as may be seen from the tables which follow. The season of 1913 was another with high precipitation, while the temperature was a fair average of the other three years, 1910 to 1912, inclusive. The following tables and charts have been compiled from the records of the United States Weather Bureau for the purpose of showing in condensed form the weather conditions that existed during the four years covered by the investigation. Figure 1 shows the precipitation for one town in each district and figure 2 the range of temperature during the growing season for three representative districts, and it is believed that a careful study of these charts will furnish a correct idea of Idaho's normal weather conditions and of the weather experienced during the four years' investigations.

TABLE I.—*Precipitation, seasons of 1910, 1911, 1912, and 1913.*

SEASON OF 1910.

Locality.	Length of record in years.	Average precipitation.		Precipitation by months.						Total for 6 months.	Per cent of normal.
		An-nual.	Apr. to Sept.	Apr.	May.	June.	July.	Aug.	Sept.		
		<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>	
Blackfoot.....	14	10.46	4.84	0.67	0.78	0.10	0.21	T.	0.47	2.23	46
Boise.....	25	12.71	4.10	1.10	1.14	.30	T.	0	.50	3.04	74
Buhl.....	3	12.22	5.13	.82	.55	.25	.28	0			
Caldwell.....	5	10.54	3.51	1.05	.84	.03	T.		.89	2.81	80
Gooding.....	1			.77	.32	.08	.24	0	.44	1.85	
Hailey.....	8	17.15	4.04	.81	.80	.06	.27	0	1.33	3.27	81
Idaho Falls.....	15	14.45	6.24	.06	.75	.14	.11	T.	1.30	2.36	38
Shoshone.....	3	15.06	2.91	.33	.43	.01	.18	0	.54	1.49	51
Twin Falls.....	5	12.90	4.40	.73	.52	.06	.12	T.	.95	2.38	54

SEASON OF 1911.

Boise.....	26	12.71	4.10	1.59	2.57	2.55	0.05	T.	0.04	6.80	166
Buhl.....	4	11.15	5.17	.86	1.97	2.34	.18	T.	T.	5.35	103
Caldwell.....	6	10.31	3.59	1.03	1.13	1.44	.23	T.	.12	3.95	110
Gooding.....	2	9.40	3.20	1.15	1.77	1.06	0	T.	T.	3.98	124
Hailey.....	9	16.27	4.30	1.67	2.91	1.53	0.04	T.	.03	6.18	144
Idaho Falls.....	16	14.00	6.00	.95	2.29	2.67	.30	0.07	.67	6.95	116
Oakley.....	18	9.58	4.61	.15	1.75	2.76	.84	0	.30	5.80	126
Twin Falls.....	6	12.10	4.19	.43	1.74	.83	.05	0.04	.10	3.19	76
Wendell.....	3	13.86	3.96	1.35	2.00	1.95	T.	0	T.	5.30	134

TABLE I.—*Precipitation, seasons of 1910, 1911, 1912, and 1913—Continued.*

SEASON OF 1912.

Locality.	Length of record in years.	Average precipitation.		Precipitation by months.						Total for 6 months.	Per cent of normal.
		Annual.	Apr. to Sept.	Apr.	May.	June.	July.	Aug.	Sept.		
		<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>	
Boise.....	27	12.71	4.10	3.34	1.94	0.86	1.27	0.07	0.77	8.25	201
Buhl.....	5	10.90	4.99	1.92	.43	.90	.13	.08	.30	3.81	76
Caldwell.....	7	10.05	4.13	1.96	2.05	1.77	1.22	.21	.50	7.71	187
Gooding.....	3	10.82	3.24	.96	1.33	.67	.33	T.	.18	3.47	107
Idaho Falls.....	17	14.23	6.19	1.94	1.36	.89	1.60	2.28	.44	8.51	137
Twin Falls.....	7	11.98	4.13	1.63	.63	.46	.48	.16	.30	3.71	90
Wendell.....	4	13.76	3.82	1.38	.57	.86	.04	T.	.31	3.16	83

SEASON OF 1913.

		<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>	
Boise.....	28	12.71	4.10	0.95	0.58	1.64	2.01	0.03	0.65	5.85	143
Buhl.....	6	11.25	5.25	.62	1.58	2.49	2.29	.13	.05	7.16	136
Gooding.....	4	11.14	3.04	.47	.15	.91	.73	.08	.05	2.39	79
Hollister.....	2	12.97	6.74	.89	1.79	2.40	1.65	.13	.49	7.35	109
Idaho Falls.....	18	14.35	6.19	.35	2.39	2.99	1.86	.08	.88	8.55	138
Oakley.....	19	9.99	4.89	.15	1.36	3.01	1.85	.84	.65	7.86	156
Rogerson.....					1.25	4.32	1.29	1.17			
Twin Falls.....	8	11.78	4.54	.53	.75	2.54	1.50	.17	2.09	7.58	167

RESULTS OBTAINED DURING 1910, 1911, 1912, AND 1913.

Tables II to VIII show in condensed form the principal results secured from the most of the experiments. It was evident that soils and crops differed so widely in their irrigation requirements that comparisons could be made only by grouping the data according to soils and crops. The crops are therefore segregated in two groups in the tables, according to their water requirements: (1) Spring and winter grains, potatoes, and orchard; (2) alfalfa, clover, and pasture. For convenience, the results from the three or more plots on each farm are grouped together so that the experiments on the different farms are separated slightly in the tables. The total depth applied includes only the irrigation water that was retained upon the tract in question, the rainfall during the growing season being given in another column.

TABLE II.—*Effects of different volumes of water on grains and potatoes in Idaho during the season of 1910.*

No. of plot.	Kind of crop.	Altitude.	Class of soil.	Area.	Precipitation April-September, inclusive.	Date of first irrigation.	Length of irrigation season.	Number of irrigations.	Total depth irrigation water applied.	Yield per acre.
		<i>Feet.</i>		<i>Acres.</i>	<i>In.</i>		<i>Days.</i>		<i>Feet.</i>	<i>Bushels.</i>
1	Oats	3,968	Slightly sandy loam	3.91	1.49	May 31	63	3	2.12	22.8
2	do	3,968	do	3.73	1.49	do	75	4	2.20	27.7
3	do	3,968	do	4.51	1.49	do	87	5	3.31	27.6
4	Wheat	3,800	Medium clay loam	4.95		June 5		1	.87	44.5
5	do	3,800	do	5.06		May 26	27	2	1.44	67.2
6	do	3,800	do	5.06		May 24	28	3	2.20	59.3
7	Wheat	4,949	Very gravelly	4.96	2.36	June 9	77	4	2.40	10.0
8	do	4,949	do	4.94	2.36	do	78	4	2.26	11.1
9	do	4,949	do	4.79	2.36	June 10	77	4	2.26	11.3
10	Oats	4,949	Very gravelly	2.93	2.36	June 3	54	4	3.26	22.0
11	Wheat	4,949	Very gravelly	4.02	2.36	June 5	54	3	3.70	24.3
12	do	4,949	do	4.98	2.36	do	54	4	4.73	82.7
13	do	4,949	do	4.93	2.36	June 4	53	5	7.08	30.2
14	Wheat	4,949	Gravelly clay	3.60	2.36	June 10	31	3	2.64	30.6
15	do	4,949	do	3.16	2.36	do	50	4	3.10	35.8
16	do	4,949	do	3.07	2.36	June 9	50	5	3.96	39.0
17	Oats	4,742	Very gravelly	2.44	2.36	June 3	71	4	4.48	21.7
18	do	4,742	do	3.78	2.36	June 4	62	4	4.14	34.2
19	do	4,742	do	4.50	2.36	June 2	79	6	5.68	33.2
20	Oats	4,742	Impervious clay loam	3.46	2.36	June 23	51	3	.99	44.5
21	do	4,742	do	3.44	2.36	June 24	52	3	1.22	49.7
22	do	4,742	do	3.66	2.36	June 22	51	3	1.71	54.3
23	Wheat	4,497	Very sandy	4.11	2.23	July 2		1	.76	27.8
24	do	4,497	do	2.72	2.23	June 25		1	1.05	26.9
25	do	4,497	do	4.76	2.23	June 9	15	2	2.93	27.3
26	Oats	2,482	Impervious clay loam	4.36	2.81	May 24	13	3	1.02	21.8
27	do	2,482	do	3.56	2.81	May 23	14	3	1.22	33.8
28	do	2,482	do	5.09	2.81	May 26	13	3	1.45	29.4
29	Wheat	2,607	Uniform clay loam	4.24	2.90	May 27	26	2	.72	36.3
30	do	2,607	do	3.84	2.90	May 23	30	2	.84	38.0
31	do	2,607	do	3.98	2.90	May 27	30	2	1.13	34.4
32	Oats	2,460	Coarse sandy loam	3.61	3.04	May 21	47	3	1.00	58.0
33	do	2,460	do	2.77	3.04	May 20	56	5	1.36	55.0
34	do	2,460	do	2.57	3.04	May 19	61	5	2.31	47.0
35	Wheat	3,800	Uniform clay loam	4.72	1.85	May 26	35	2	.55	8.3
36	do	3,800	do	4.55	1.85	do	35	2	.89	15.9
37	do	3,800	do	4.43	1.85	do	35	2	.95	12.4
38	Oats	2,482	Impervious clay loam	5.16	2.81	June 15	41	4	.65	16.1
39	do	2,482	do	4.03	2.81	June 14	59	5	1.03	25.4
40	do	2,482	do	4.31	2.81	June 18	57	6	1.22	27.3
41	Wheat	3,572	Medium clay loam	.172	1.85			0	.00	436.0
42	do	3,572	do	.089	1.85	May 20	25	2	.533	1,123.6
43	do	3,572	do	.088	1.85	do	43	3	.713	1,397.7
44	do	3,572	do	.091	1.85	do	43	4	.842	1,824.2
45	do	3,572	do	.084	1.85	do	54	5	1.210	2,000.0
46	do	3,572	do	.092	1.85	do	61	6	1.435	2,010.0
47	do	3,572	do	.083	1.85	May 21	66	9	2.486	2,084.3
48	Wheat	3,572	Medium clay loam	.195	1.85			0	.000	605.1
49	do	3,572	do	.088	1.85	May 20	25	2	.352	1,227.3
50	do	3,572	do	.088	1.85	do	43	3	.533	1,238.6
51	do	3,572	do	.086	1.85	do	43	4	.945	1,430.2
52	do	3,572	do	.089	1.85	do	54	5	1.100	1,932.6
53	do	3,572	do	.074	1.85	do	61	6	1.601	2,067.5
54	do	3,572	do	.089	1.85	May 21	66	9	2.355	2,101.1

TABLE II.—*Effects of different volumes of water on grains and potatoes in Idaho during the season of 1910—Continued.*

No. of plot.	Kind of crop.	Altitude.	Class of soil.	Area.	Precipitation April-September, inclusive.	Date of first irrigation.	Length of irrigation season.	Number of irrigations.	Total depth irrigation water applied.	Yield per acre.
		<i>Feet.</i>		<i>Acres.</i>	<i>In.</i>		<i>Days.</i>		<i>Feet.</i>	<i>Pounds.</i>
55	Wheat..	3,572	Medium clay loam.....	0.176	1.85			0	0.000	522.7
56	do.....	3,572	do.....	.088	1.85	May 20	25	2	.434	1,227.3
57	do.....	3,572	do.....	.089	1.85	do.....	43	3	.594	1,359.7
58	do.....	3,572	do.....	.091	1.85	do.....	43	4	.907	1,824.2
59	do.....	3,572	do.....	.088	1.85	do.....	54	5	1.091	2,102.3
60	do.....	3,572	do.....	.093	1.85	May 21	60	7	1.786	2,258.0
61	do.....	3,572	do.....	.074	1.85	do.....	66	9	3.010	2,635.1
62	Barley..	3,572	Medium clay loam.....	.962	1.85	May 17	32	3	1.032	1,509.4
63	do.....	3,572	do.....	.963	1.85	do.....	58	4	1.312	1,797.5
64	do.....	3,572	do.....	.968	1.85	May 18	68	5	1.879	2,026.9
65	Oats....	3,572	Medium clay loam.....	.959	1.85	May 24	23	2	.560	1,444.2
66	do.....	3,572	do.....	.957	1.85	May 25	41	3	1.097	1,849.5
67	do.....	3,572	do.....	.962	1.85	May 23	51	4	1.450	2,047.8
68	Wheat..	3,572	Medium clay loam.....	.563	1.85	May 26	22	2	.780	1,179.4
69	do.....	3,572	do.....	.591	1.85	do.....	40	3	1.269	1,539.8
70	do.....	3,572	do.....	.769	1.85	do.....	60	4	1.841	1,581.3
71	Wheat..	3,572	Medium clay loam.....	.959	1.85	May 9	23	2	.808	1,379.4
72	do.....	3,572	do.....	.964	1.85	do.....	42	3	1.101	1,211.6
73	do.....	3,572	do.....	.968	1.85	do.....	51	4	1.327	1,742.8
74	Potatoes	3,572	Medium clay loam.....	.641	1.85	May 13	63	3	.876	6,302.6
75	do.....	3,572	do.....	.652	1.85	do.....	88	5	1.496	11,932.5
76	do.....	3,572	do.....	.636	1.85	do.....	97	6	2.046	12,932.3
77	Oats....	3,572	Medium clay loam.....	5.70	1.85	May 12	64	3	1.401	<i>Bushels.</i> 43.3
78	do.....	3,572	do.....	4.48	1.85	May 17	60	4	1.766	54.6
79	do.....	3,572	do.....	1.98	1.85	May 19	59	4	2.486	73.7

TABLE III.—*Effects of different volumes of water on alfalfa, clover, and pasture during the season of 1910.*

No. of plot.	Kind of crop.	Altitude.	Class of soil.	Area.	Precipitation April-September, inclusive.	Date of first irrigation.	Length of irrigation season.	Number of irrigations.	Total depth irrigation water applied.	Yield per acre.
		<i>Feet.</i>		<i>Acres.</i>	<i>In.</i>		<i>Days.</i>		<i>Feet.</i>	<i>Tons.</i>
1	Alfalfa..	3,572	Medium clay loam.....	0.983	1.85	May 8	88	6	4.49	8.7
2	Alfalfa..	3,572	Medium clay loam.....	5.75	1.85	May 7	43	2	1.306	3.30
3	do.....	3,572	do.....	3.72	1.85	May 9	79	3	1.872	3.56
4	do.....	3,572	do.....	3.56	1.85	May 10	78	3	2.104	4.74
5	Alfalfa..	4,949	Very gravelly.....	10.65	2.36	May 27	88	9	11.20	4.2
6	Red clo- ver.....	4,949	Very gravelly.....	3.31	2.36	May 6	113	7	6.92	3.78
7	do.....	4,949	do.....	4.32	2.36	May 7	117	9	8.40	4.85
8	do.....	4,949	do.....	3.98	2.36	May 4	114	10	12.98	4.60
9	Alfalfa..	4,949	Very gravelly.....	2.33	2.36	May 3	101	4	6.352	3.78
10	do.....	4,949	do.....	6.77	2.36	May 2	105	6	6.925	3.65
11	do.....	4,949	do.....	2.51	2.36	Apr. 27	110	7	9.401	5.20

TABLE III.—*Effects of different volumes of water on alfalfa, clover, and pasture during the season of 1910—Continued.*

No. of plot.	Kind of crop.	Altitude.	Class of soil.	Area.	Precipitation April-September, inclusive.	Date of first irrigation.	Length of irrigation season.	Number of irrigations.	Total depth irrigation water applied.	Yield per acre.
		<i>Feet.</i>		<i>Acres.</i>	<i>In.</i>		<i>Days.</i>		<i>Feet.</i>	<i>Tons.</i>
12	Alfalfa..	4,742	Uniform clay loam.....	3.20	2.36	May 6	104	4	1.409	5.04
13	..do....	4,742	..do.....	3.16	2.36	..do....	102	6	1.953	3.41
14	..do....	4,742	..do.....	3.37	2.36	..do....	103	6	2.221	5.72
15	Alfalfa..	4,497	Very sandy.....	3.38	2.23	May 27	36	3	1.609	4.44
16	..do....	4,497	..do.....	4.15	2.23	..do....	50	5	2.649	4.28
17	..do....	4,497	..do.....	4.29	2.23	..do....	59	7	4.825	4.57
18	Alfalfa..	2,367	Impervious clay loam.....	2.81	2.81	Mar. 29	144	8	1.895	4.06
19	..do....	2,367	..do.....	3.69	2.81	Mar. 27	143	8	2.848	3.66
20	..do....	2,367	..do.....	2.84	2.81	Mar. 28	144	9	3.457	4.37
21	Alfalfa..	2,482	Impervious clay loam.....	6.32	3.00	May 7	115	7	1.434	2.85
22	..do....	2,482	..do.....	6.23	3.00	May 5	120	7	2.112	4.93
23	..do....	2,482	..do.....	6.21	3.00	..do....	99	7	2.251	4.35
24	Alfalfa..	2,607	Uniform clay loam.....	5.08	2.80	Apr. 28	109	6	2.821	5.15
25	Alfalfa..	5,820	Very gravelly.....	158.4	3.27	.....	120	.....	21.13	3 to 3.5
26	Alfalfa..	5,330	Very gravelly.....	15.2	3.27	.....	120	.....	16.00	3 to 4
27	Alfalfa..	3,572	Clay loam.....	51.0	1.85	.....	140	.....	4.80	4
28	Alfalfa..	3,572	Uniform clay loam.....	31.8	1.85	.....	140	.....	4.06	4
29	Alfalfa and wheat.	3,572	Uniform clay loam.....	69.6	1.85	.....	140	.....	4.00	4
30	Alfalfa..	3,800	Medium clay loam.....	2.92	3.04	May 4	105	4	2.34	6.86
31	..do....	3,800	..do.....	2.89	3.04	May 5	107	4	4.05	7.04
32	..do....	3,800	..do.....	3.38	3.04	May 7	109	4	4.72	7.96

TABLE IV.—*Effects of different volumes of water on grains, orchards, and potatoes in Idaho during the season of 1911.*

No. of plot.	Kind of crop.	Altitude.	Class of soil.	Area.	Precipitation April-September, inclusive.	Date of first irrigation.	Length of irrigation season.	Number of irrigations.	Total depth irrigation water applied.	Yield per acre.
		<i>Feet.</i>		<i>Acres.</i>	<i>In.</i>		<i>Days.</i>		<i>Feet.</i>	<i>Bushels.</i>
1	Oats....	3,968	Uniform sandy loam.....	3.56	6.18	July 12	.....	1	0.453	29.5
2	..do....	3,968	..do.....	3.66	6.18	June 21	26	2	1.144	45.9
3	..do....	3,968	..do.....	4.15	6.18	June 17	42	3	1.889	50.8
4	Wheat..	3,800	Shallow clay loam.....	4.24	5.35	June 11	15	2	.864	30.6
5	..do....	3,800	..do.....	4.73	5.35	June 7	43	3	1.623	33.8
6	..do....	3,800	..do.....	3.25	5.35	June 5	51	4	2.153	38.0
7	Wheat..	3,750	Medium clay loam.....	3.59	5.50	June 24	19	2	.635	63.2
8	..do....	3,750	..do.....	7.49	5.50	June 17	32	2	1.123	53.4
9	..do....	3,750	..do.....	5.42	5.50	June 14	27	2	1.808	64.0
10	Oats....	3,750	Medium clay loam.....	5.80	5.50	June 2	52	3	1.161	64.3
11	..do....	3,750	..do.....	4.82	5.50	June 1	47	3	1.414	51.9
12	..do....	3,750	..do.....	7.02	5.50	May 29	64	4	1.442	65.3
13	Oats....	3,825	Medium clay loam.....	4.01	3.19	June 28	.....	1	.302	56.6
14	..do....	3,825	..do.....	6.10	3.19	June 20	35	2	1.167	63.2
15	..do....	3,825	..do.....	4.03	3.19	June 8	53	3	2.266	68.9

TABLE IV.—*Effects of different volumes of water on grains, orchards, and potatoes in Idaho during the season of 1911—Continued.*

No. of plot.	Kind of crop.	Altitude, Feet.	Class of soil.	Area, Acres.	Precipitation April-September, inclusive, In.	Date of first irrigation.	Length of irrigation season, Days.	Number of irrigations.	Total depth irrigation water applied, Feet.	Yield per acre, Bushels. (1)
16	Orchard.	3,825	Medium clay loam.....	4.58	3.19	July 6	.....	1	.268	
17	Fall rye.	3,700	Very sandy loam.....	6.89	5.30	May 12	.....	1	.729	11.6
18	Oats....	3,700	Very sandy loam.....	4.29	5.30	June 8	45	3	.656	23.3
19	do.....	3,700	do.....	4.01	5.30	June 6	43	3	.888	26.0
20	do.....	3,700	do.....	4.17	5.30	June 1	54	4	1.047	35.0
21	Potatoes	3,700	Extremely sandy.....	2.89	5.30	July 12	40	3	.613	112.8
22	do.....	3,700	do.....	2.90	5.30	June 19	46	3	.955	108.1
23	do.....	3,700	do.....	3.27	5.30	June 22	59	4	1.062	128.1
24	Oats....	4,100	Deep clay loam.....	4.98	5.80	June 25	.....	1	.641	76.5
25	do.....	4,100	do.....	5.11	5.80	June 22	.....	1	1.316	73.5
26	do.....	4,100	do.....	4.42	5.80	June 15	.....	1	1.654	72.4
27	Wheat..	4,949	Very gravelly.....	15.51	6.95	July 3	49	3	1.377	20.9
28	Wheat..	4,949	Shallow sandy loam.....	14.91	6.95	June 16	53	3	5.342	30.0
29	Potatoes	4,949	Sandy loam.....	7.11	6.95	July 20	46	4	2.828	211.8
30	Wheat..	4,949	Shallow sandy loam.....	9.83	6.95	June 20	42	3	3.466	31.6
31	Oats....	4,949	Sandy loam.....	3.85	6.95	July 16	36	3	4.511	31.8
32	do.....	4,949	do.....	2.55	6.95	June 30	54	4	5.943	68.4
33	do.....	4,949	do.....	2.96	6.95	June 28	53	5	10.366	57.2
34	Wheat..	2,600	Impervious clay loam.....	8.47	4.09	June 1	39	2	.307	19.7
35	do.....	2,600	do.....	11.05	4.09	June 7	.....	1	.315	16.0
36	do.....	2,600	do.....	8.64	4.09	June 5	38	3	.589	22.0
37	Wheat..	2,600	Impervious clay loam.....	2.05	4.09	June 25	19	3	.263	12.0
38	do.....	2,600	do.....	1.19	4.09	June 26	15	2	.271	5.0
39	do.....	2,600	do.....	1.65	4.09	June 25	22	3	.497	5.0
40	Oats....	2,600	Impervious clay loam.....	3.06	4.09	June 24	18	2	.294	22.0
41	do.....	2,600	do.....	2.08	4.09	June 23	21	3	.372	26.0
42	do.....	2,600	do.....	2.60	4.09	June 24	23	3	.417	26.0
43	Oats....	2,600	Sandy loam.....	5.38	4.09	May 30	.....	1	.185	16.0
44	do.....	2,600	do.....	7.29	4.09	May 24	.....	1	.199	10.6
45	do.....	2,600	do.....	6.25	4.09	June 3	.....	1	.248	17.7
46	Oats....	2,607	Impervious clay loam.....	4.56	6.80	June 12	25	2	.557	28.0
47	do.....	2,607	do.....	1.35	6.80	do.....	25	2	.618	34.8
48	do.....	2,607	do.....	3.69	6.80	June 13	24	2	.769	31.4
49	Oats....	2,460	Clay loam.....	2.58	6.80	June 2	28	2	.461	43.0
50	do.....	2,460	do.....	2.30	6.80	June 4	38	3	.698	63.0
51	do.....	2,460	do.....	2.37	6.80	June 3	39	3	1.076	73.0
52	Wheat..	2,607	Sandy loam.....	2.56	6.80	June 8	23	2	1.193	49.0
53	Wheat..	2,607	do.....	6.17	6.80	June 8	38	3	1.371	35.5
54	do.....	2,607	do.....	5.79	6.80	do.....	23	2	1.428	37.6
55	Wheat..	2,460	Sandy loam mixed with clay	4.40	6.80	June 27	19	2	.770	45.4
56	do.....	2,460	do.....	5.55	6.80	June 25	19	2	1.367	49.5
57	Oats....	2,547	Sandy loam.....	6.72	6.80	June 12	35	3	1.258	47.3
58	do.....	2,547	do.....	4.16	6.80	June 7	32	2	1.315	59.3
59	do.....	2,547	do.....	5.67	6.80	June 5	32	3	3.095	54.1
60	Wheat..	2,400	Coarse sandy loam.....	3.74	6.80	June 9	33	2	.866	27.8
61	do.....	2,400	do.....	6.21	6.80	do.....	34	3	1.186	43.96
62	do.....	2,400	do.....	4.14	6.80	June 10	34	3	1.253	33.59

1 Four years old, no crop.

TABLE IV.—*Effects of different volumes of water on grains, orchards, and potatoes in Idaho during the season of 1911—Continued.*

No. of plot.	Kind of crop.	Altitude.	Class of soil.	Area.	Precipitation April-September, inclusive.	Date of first irrigation.	Length of irrigation season.	Number of irrigations.	Total depth irrigation water applied.	Yield per acre.
		<i>Feet.</i>		<i>Acres.</i>	<i>In.</i>		<i>Days.</i>		<i>Feet.</i>	<i>Bushels.</i>
63	Oats....	5,330	Very gravelly.....	4.03	6.18	July 15	18	2	3.187	45.6
64	..do....	5,330	..do.....	8.63	6.18	July 12	20	2	4.280	39.9
65	..do....	5,330	..do.....	5.55	6.18	June 23	38	3	6.304	40.9
66	Orchard	2,460	Clay loam.....	35.00	6.80		122		4.25	(1)
67	Orchard	2,547	Coarse sandy loam.....	13.15	6.80		122		5.26	(1)
68	Orchard	2,641	Clay loam.....	31.85	6.80		122		3.56	(1)
69	Orchard	2,641	Clay loam.....	39.72	6.80		122		2.32	(1)
70	{ Grain and alfalfa. }	5,330	Very gravelly.....	35.59	6.18	June 13	71	....	9.484	{ ²³ 30 } <i>Bushels.</i>
71	Oats....	2,600	Impervious clay loam.....	2.02	4.09	May 11	64	4	.525	11.0
72	..do....	2,600	..do.....	2.03	4.09	May 13	59	5	.825	31.0
73	..do....	2,600	..do.....	2.03	4.09	May 12	61	5	.967	33.5
74	Corn....	3,700	Extremely sandy.....	3.91	5.30	June 20	54	3	.789	<i>Tons.</i> 4.00
75	..do....	3,700	..do.....	4.34	5.30	June 22	57	3	.789	4.00
76	..do....	3,700	..do.....	4.66	5.30	June 20	57	3	1.381	4.00
77	Wheat..	3,572	Medium clay loam.....	.189	3.98			0	.000	<i>Pounds.</i> 952.37
78	..do....	3,572	..do.....	.092	3.98	June 1		1	.479	1,108.69
79	..do....	3,572	..do.....	.096	3.98	June 2	41	3	1.285	1,322.91
80	..do....	3,572	..do.....	.097	3.98	..do....	42	5	1.516	1,371.13
81	..do....	3,572	..do.....	.092	3.98	..do....	48	4	1.737	1,565.21
82	..do....	3,572	..do.....	.091	3.98	..do....	55	7	2.558	1,472.53
83	..do....	3,572	..do.....	.092	3.98	June 3	54	10	2.820	1,021.73
84	Wheat..	3,572	Medium clay loam.....	.189	3.98			0	.000	973.54
85	..do....	3,572	..do.....	.094	3.98	June 1		1	.379	1,095.74
86	..do....	3,572	..do.....	.093	3.98	June 2	42	3	1.184	1,193.54
87	..do....	3,572	..do.....	.095	3.98	..do....	48	4	1.374	1,389.47
88	..do....	3,572	..do.....	.092	3.98	..do....	42	5	1.861	1,130.43
89	..do....	3,572	..do.....	.094	3.98	..do....	55	7	2.853	1,351.06
90	..do....	3,572	..do.....	.094	3.98	June 3	54	10	3.156	797.87
91	Wheat..	3,572	Medium clay loam.....	.189	3.98			0	.000	1,063.49
92	..do....	3,572	..do.....	.091	3.98	June 1		1	.417	1,285.71
93	..do....	3,572	..do.....	.093	3.98	June 2	42	3	1.148	1,709.67
94	..do....	3,572	..do.....	.090	3.98	..do....	48	4	1.451	1,833.33
95	..do....	3,572	..do.....	.094	3.98	..do....	42	5	1.842	1,563.83
96	..do....	3,572	..do.....	.093	3.98	June 3	54	7	2.161	1,139.78
97	..do....	3,572	..do.....	.096	3.98	..do....	54	10	2.834	968.75
98	Oats....	3,572	Medium clay loam.....	.63	3.98	June 16		1	.376	1,333.33
99	..do....	3,752	..do.....	.63	3.98	June 10	30	3	.962	1,501.58
100	..do....	3,752	..do.....	.61	3.98	June 6	42	5	1.533	1,670.49
101	Wheat..	3,572	Medium clay loam.....	.990	3.98	June 9		1	.460	1,719.19
102	..do....	3,572	..do.....	.982	3.98	June 5	17	2	1.400	1,450.10
103	..do....	3,572	..do.....	.982	3.98	June 3	34	4	1.402	1,446.02
104	Barley..	3,572	Medium clay loam.....	.985	3.98	June 21		1	.555	1,470.05
105	..do....	3,572	..do.....	.965	3.98	June 18	20	2	.953	1,842.48
106	..do....	3,572	..do.....	.951	3.98	June 17	30	3	1.678	1,590.95
107	Wheat..	3,572	Medium clay loam.....	.610	3.98	June 15		1	.419	1,754.09
108	..do....	3,572	..do.....	.622	3.98	June 13	34	3	.909	1,860.12
109	..do....	3,572	..do.....	.641	3.98	June 14	40	5	1.788	1,893.91
110	Potatoes	3,572	Medium clay loam.....	.630	3.98	July 9		1	.539	7,349.2
111	..do....	3,572	..do.....	.630	3.98	July 2	40	5	2.208	16,738.0
112	..do....	3,572	..do.....	.610	3.98	June 29	41	5	3.644	16,754.0

¹ Yield not measured.² Tons alfalfa.³ Bushels oats.

TABLE V.—*Effects of different volumes of water on alfalfa, clover, and pasture during the season of 1911.*

No. of plot.	Kind of crop.	Altitude.	Class of soil.	Area.	Precipitation April-September, inclusive.	Date of first irrigation.	Length of irrigation season.	Number of irrigations.	Total depth irrigation water applied.	Yield per acre.
		<i>Feet.</i>		<i>Acres.</i>	<i>In.</i>		<i>Days.</i>		<i>Feet.</i>	<i>Pounds.</i>
1	Alfalfa..	3,572	Medium clay loam.....	0.943	3.98	May 10	105	3	1.775	7,534.0
2	..do....	3,572	..do.....	.930	3.98	..do....	128	6	3.329	10,608.0
3	..do....	3,572	..do.....	.965	3.98	May 11	128	8	4.000	13,233.0
4	Alfalfa..	3,800	Shallow clay loam.....	4.69	5.35	May 9	109	4	1.962	<i>Tons.</i> 5.83
5	..do....	3,800	..do.....	5.38	5.35	May 12	116	6	2.327	5.57
6	..do....	3,800	..do.....	3.85	5.35	May 8	108	5	2.549	5.25
7	Alfalfa..	3,750	Medium clay loam.....	3.72	5.35	May 31	86	4	2.677	4.56
8	..do....	3,750	..do.....	2.67	5.35	May 21	95	5	3.263	6.00
9	..do....	3,750	..do.....	3.76	5.35	May 19	119	6	3.756	6.00
10	Alfalfa..	3,800	Medium clay loam.....	4.17	3.19	May 4	80	2	1.286	6.1
11	..do....	3,800	..do.....	4.22	3.19	May 6	135	4	3.194	6.4
12	..do....	3,800	..do.....	4.96	3.19	May 8	135	5	3.981	5.76
13	Alfalfa..	3,825	Medium clay loam.....	4.37	3.19	May 17	105	3	1.309	4.73
14	..do....	3,825	..do.....	4.19	3.19	May 13	112	4	2.767	5.44
15	..do....	3,825	..do.....	4.78	3.19	May 14	106	5	3.211	4.97
16	Alfalfa..	3,700	Very sandy loam.....	2.65	5.30	May 10	119	6	1.894	1.50
17	..do....	3,700	..do.....	1.80	5.30	May 4	125	6	2.611	2.74
18	Alfalfa..	4,100	Deep clay loam.....	9.98	5.80	May 20	.....	1	.993	3.1
19	Alfalfa..	4,949	Very gravelly.....	10.65	6.95	May 19	108	8	11.532	4.54
20	Alfalfa..	4,949	Very gravelly.....	5.45	6.95	May 22	77	4	5.402	1.99
21	..do....	4,949	..do.....	5.28	6.95	May 23	94	7	6.400	3.42
22	..do....	4,949	..do.....	5.73	6.95	May 22	94	6	7.224	3.27
23	Clover..	4,949	Very gravelly.....	3.31	6.95	May 20	88	5	5.246	2.60
24	..do....	4,949	..do.....	4.32	6.95	..do....	103	7	6.611	3.25
25	..do....	4,949	..do.....	3.98	6.95	May 19	109	9	14.721	2.91
26	Alfalfa..	2,607	Clay loam.....	3.37	6.80	June 3	103	7	1.535	1.1
27	..do....	2,607	..do.....	3.48	6.80	..do....	103	8	2.912	1.1
28	..do....	2,607	..do.....	3.37	6.80	..do....	103	8	4.114	1.89
29	Alfalfa..	2,607	Impervious clay loam.....	4.94	6.80	Apr. 26	141	9	2.136	2.11
30	..do....	2,607	..do.....	4.21	6.80	Apr. 25	142	11	3.511	3.93
31	..do....	2,607	..do.....	9.39	6.80	..do....	141	12	3.814	4.39
32	Timothy and clover.	2,547	Dark sandy loam.....	5.43	6.80	Apr. 21	122	7	3.257	4.63
33	..do....	2,547	..do.....	5.46	6.80	Apr. 26	119	8	4.437	4.57
34	..do....	2,547	..do.....	4.53	6.80	Apr. 25	119	9	6.040	3.84
35	Alfalfa and grain.	5,820	Very gravelly.....	156.3	6.18	June 11	67	....	10.91	3.00
36	Alfalfa..	5,330	Very gravelly.....	40.49	6.18	June 15	65	....	8.562	3.00

¹ New seeding, first year.

TABLE VI.—*Effects of different volumes of water on grains, orchards, and potatoes in Idaho during the season of 1912.*

No. of plot.	Kind of crop.	Altitude.	Class of soil.	Area.	Precipitation, April-September, inclusive.	Date of first irrigation.	Length of irrigation season.	Number of irrigations.	Total depth irrigation water applied.	Yield per acre.
		<i>Fect.</i>		<i>Acres.</i>	<i>In.</i>		<i>Days.</i>		<i>Fect.</i>	<i>Bushels.</i>
1	Wheat..	3,800	Medium clay loam.....	2.37	3.71	June 21	.....	1	0.735	67.5
2	do.....	3,800	do.....	6.54	3.71	June 24	.....	1	.871	72.1
3	do.....	3,800	do.....	8.27	3.71	June 18	36	2	1.158	82.9
4	Orchard.	3,825	Medium clay loam.....	4.58	3.71	Aug. 1	.....	1	.143	(¹)
5	Wheat..	4,000	Shallow gravelly.....	5.68	3.71	June 7	22	2	.927	31.16
6	do.....	4,000	Clay.....	7.72	3.71	June 9	35	3	1.436	37.65
7	do.....	4,000	do.....	4.16	3.71	June 6	51	4	1.598	28.60
8	Oats....	4,000	Shallow clay loam.....	1.83	3.71	June* 5	39	2	.487	10.92
9	do.....	4,000	do.....	3.86	3.71	June 3	53	3	1.427	25.90
10	do.....	4,000	do.....	3.23	3.71	June 1	57	4	1.748	24.76
11	Wheat..	3,800	Shallow clay loam.....	6.91	3.81	June 26	.....	1	.276	15.92
12	do.....	3,800	do.....	6.05	3.81	June 18	37	2	.791	18.02
13	do.....	3,800	do.....	6.09	3.81	June 23	34	3	1.214	24.11
14	Wheat..	3,750	Deep clay loam.....	4.85	3.81	June 3	39	2	.967	39.59
15	do.....	3,750	do.....	4.41	3.81	June 4	60	3	1.655	43.76
16	do.....	3,750	do.....	4.78	3.81	June 2	61	3	2.053	42.05
17	Orchard.	3,800	Shallow clay loam.....	8.40	3.81	July 12	.....	1	.093	(¹)
18	Wheat..	2,763	Impervious clay loam.....	.153	8.25	.....	.....	0	.000	<i>Pounds.</i> 784.3
19	do.....	2,763	do.....	.170	8.25	June 25	.....	1	.344	1,058.81
20	do.....	2,763	do.....	.184	8.25	do.....	9	2	.529	1,304.32
21	do.....	2,763	do.....	.173	8.25	June 12	22	3	.690	1,734.09
22	do.....	2,763	do.....	.161	8.25	do.....	36	4	.950	1,863.33
23	do.....	2,763	do.....	.178	8.25	do.....	36	4	.862	2,022.48
24	do.....	2,763	do.....	.165	8.25	do.....	43	5	1.042	3,272.72
25	Wheat..	2,607	Impervious clay loam.....	3.98	8.25	June 5	39	2	.780	<i>Bushels.</i> 34.92
26	do.....	2,607	do.....	1.42	8.25	June 7	51	3	.951	37.32
27	do.....	2,607	do.....	3.57	8.25	June 3	54	4	1.186	38.38
28	Wheat..	2,607	Clay loam.....	13.36	8.25	June 19	30	2	2.473	31.81
29	Oats....	4,949	Very gravelly.....	5.40	8.51	June 28	40	3	2.953	76.7
30	do.....	4,949	do.....	5.52	8.51	June 29	48	3	3.236	63.0
31	do.....	4,949	do.....	5.73	8.51	June 28	49	3	4.263	74.7
32	Wheat..	3,572	Medium clay loam.....	.689	3.47	May 29	.....	1	.638	<i>Pounds.</i> 2,367.3
33	do.....	3,572	do.....	.636	3.47	May 28	23	2	1.087	2,336.1
34	do.....	3,572	do.....	.625	3.47	May 27	30	4	1.653	2,326.7
35	Wheat..	3,572	Medium clay loam.....	.186	3.47	.....	.....	0	.000	1,087.7
36	do.....	3,572	do.....	.097	3.47	June 3	.....	1	.589	1,104.2
37	do.....	3,572	do.....	.088	3.47	do.....	30	3	1.244	1,530.6
38	do.....	3,572	do.....	.094	3.47	June 4	28	4	1.475	1,525.4
39	do.....	3,572	do.....	.091	3.47	do.....	44	6	1.806	1,444.3
40	do.....	3,572	do.....	.093	3.47	do.....	44	7	2.381	1,652.3
41	do.....	3,572	do.....	.089	3.47	do.....	52	10	2.638	2,022.3
42	Wheat..	3,572	Medium clay loam.....	.186	3.47	.....	.....	0	.000	912.7
43	do.....	3,572	do.....	.091	3.47	June 3	.....	1	.343	1,207.2
44	do.....	3,572	do.....	.092	3.47	do.....	29	3	1.190	1,207.8
45	do.....	3,572	do.....	.088	3.47	June 4	28	4	1.179	1,775.6
46	do.....	3,572	do.....	.094	3.47	do.....	44	6	2.125	1,483.0
47	do.....	3,572	do.....	.090	3.47	do.....	44	7	2.216	1,770.9
48	do.....	3,572	do.....	.097	3.47	do.....	52	10	2.798	1,780.2
49	Wheat..	3,572	Medium clay loam.....	.183	3.47	.....	.....	0	.000	1,042.5
50	do.....	3,572	do.....	.094	3.47	June 3	.....	1	.481	1,122.8
51	do.....	3,572	do.....	.090	3.47	do.....	29	3	1.273	1,407.8
52	do.....	3,572	do.....	.092	3.47	June 4	29	4	1.272	1,469.0
53	do.....	3,572	do.....	.086	3.47	do.....	44	6	1.815	1,586.9
54	do.....	3,572	do.....	.094	3.47	do.....	45	7	2.146	1,536.0
55	do.....	3,572	do.....	.084	3.47	do.....	52	10	2.436	1,846.0

¹ Only 5 years old, small yield not measured.

TABLE VI.—*Effects of different volumes of water on grains, orchards, and potatoes in Idaho during the season of 1912—Continued.*

No. of plot.	Kind of crop.	Altitude.	Class of soil.	Area.	Precipitation, April-September, inclusive.	Date of first irrigation.	Length of irrigation season.	Number of irrigations.	Total depth irrigation water applied.	Yield per acre.
		<i>Feet.</i>		<i>Acres.</i>	<i>In.</i>		<i>Days.</i>		<i>Feet.</i>	<i>Pounds.</i>
56	Oats....	3,572	Medium clay loam.....	383	3.47	June 6	36	1	0.418	2,362.3
57	do.....	3,572	do.....	378	3.47	do.....	36	3	.857	2,992.3
58	do.....	3,572	do.....	383	3.47	June 4	43	5	1.267	3,333.3
59	do.....	3,572	do.....	390	3.47	June 5	49	7	1.577	3,264.9
60	do.....	3,572	do.....	334	3.47	June 4	50	9	2.036	3,830.5
61	Barley..	3,572	Medium clay loam.....	325	3.47	June 11	43	1	.434	2,505.3
62	do.....	3,572	do.....	326	3.47	do.....	29	3	1.061	4,074.1
63	do.....	3,572	do.....	312	3.47	June 12	37	5	1.521	4,320.5
64	Potatoes	3,572	Medium clay loam.....	627	3.47	July 1	17	2	.541	12,135.0
65	do.....	3,572	do.....	628	3.47	June 30	44	5	1.943	18,613.0
66	do.....	3,572	do.....	636	3.47	June 29	53	7	2.516	16,681.0

TABLE VII.—*Effects of different volumes of water on alfalfa during the season of 1912.*

No. of plot.	Kind of crop.	Altitude.	Class of soil.	Area.	Precipitation April-September, inclusive.	Date of first irrigation.	Length of irrigation season.	Number of irrigations.	Total depth irrigation water applied.	Yield per acre.
		<i>Feet.</i>		<i>Acres.</i>	<i>In.</i>		<i>Days.</i>		<i>Feet.</i>	<i>Pounds.</i>
1	Alfalfa..	3,572	Medium clay loam.....	0.372	3.47	May 27	44	2	0.615	5,695.0
2	do.....	3,572	do.....	.585	3.47	May 14	65	4	1.308	8,003.0
3	do.....	3,572	do.....	.372	3.47	do.....	78	7	2.059	10,828.0
4	do.....	3,572	do.....	.569	3.47	do.....	84	9	2.533	11,317.0
5	do.....	3,572	do.....	.369	3.47	do.....	88	11	2.931	12,506.0
6	do.....	3,572	do.....	.580	3.47	May 15	86	13	4.003	12,612.0
7	Alfalfa..	3,800	Medium clay loam.....	6.02	3.71	May 22	95	3	1.708	<i>Tons.</i> 5.94
8	do.....	3,800	do.....	7.49	3.71	May 24	90	3	2.070	5.84
9	do.....	3,800	do.....	7.71	3.71	May 16	123	6	3.381	5.70
10	Alfalfa..	3,800	Shallow clay loam.....	4.24	3.81	May 14	107	7	2.339	6.44
11	do.....	3,800	do.....	3.38	3.81	do.....	107	6	2.513	5.90
12	do.....	3,800	do.....	3.75	3.81	May 13	107	9	3.153	7.04
13	Alfalfa..	3,750	Deep clay loam.....	4.74	3.81	May 31	97	3	1.064	4.67
14	do.....	3,750	do.....	4.82	3.81	May 24	92	4	1.589	4.42
15	do.....	3,750	do.....	5.28	3.81	do.....	100	4	1.799	4.80
16	Alfalfa..	3,800	Shallow clay loam.....	14.28	3.81	May 27	98	4	2.413	6.00
17	Alfalfa..	2,607	Clay loam.....	4.77	8.25	May 17	101	6	1.870	4.31
18	do.....	2,607	do.....	3.62	8.25	May 16	98	6	2.961	4.11
19	do.....	2,607	do.....	6.10	8.25	May 19	105	7	2.887	3.89
20	Alfalfa..	4,949	Porous gravelly.....	4.36	8.51	May 31	75	5	1.983	2.52
21	do.....	4,949	do.....	4.94	8.51	June 21	55	3	2.027	1.48
22	do.....	4,949	do.....	4.75	8.51	June 1	75	6	2.582	1.58
23	Alfalfa..	4,949	Porous gravelly.....	3.68	8.51	June 4	71	4	3.047	1.82
24	do.....	4,949	do.....	2.65	8.51	June 5	71	4	3.307	2.00
25	do.....	4,949	do.....	2.13	8.51	June 4	71	4	6.721	2.50

TABLE VIII.—*Effects of different volumes of water on grains, alfalfa, orchards, potatoes, and sugar beets during the season of 1913.*

No. of plot.	Kind of crop.	Altitude.	Class of soil.	Area.	Precipitation April-September, inclusive.	Date of first irrigation.	Length of irrigation season.	Number of irrigations.	Total depth irrigation water applied.	Yield per acre.
		<i>Feet.</i>		<i>Acres.</i>	<i>In.</i>		<i>Days.</i>		<i>Feet.</i>	<i>Tons.</i>
1	Alfalfa..	4,500	Clay loam.....	2.70	7.35	May 31	90	3	1.2850	3.06
2	do.....	4,500	do.....	3.45	7.35	do.....	87	4	1.9607	2.51
3	do.....	4,500	do.....	3.44	7.35	May 30	89	6	2.6876	3.03
4	Big "4" oats.	4,550	Clay loam.....	5.08	7.35	July 2	.....	1	.3554	<i>Bushels.</i> 33.85
5	do.....	4,550	do.....	5.06	7.35	June 30	29	2	.8939	36.95
6	do.....	4,550	do.....	5.07	7.35	June 28	29	2	1.3291	33.82
7	Wheat..	4,550	Clay loam.....	3.01	7.35	June 22	23	2	.9954	24.24
8	do.....	4,550	do.....	4.17	7.35	June 24	38	3	1.6230	25.77
9	do.....	4,550	do.....	3.03	7.35	June 6	58	4	2.3346	16.99
10	Wheat..	4,550	Clay loam.....	3.53	7.35	May 10	109	5	2.3445	17.13
11	do.....	4,550	do.....	6.06	7.35	May 14	99	4	2.6808	18.72
12	do.....	4,550	do.....	4.45	7.35	May 10	105	5	3.2882	20.45
13	Alfalfa..	4,850	Deep uniform clay loam.....	7.52	7.35	May 29	63	2	1.4190	<i>Tons.</i> 3.83
14	do.....	4,850	do.....	5.12	7.35	May 7	107	3	2.4645	4.00
15	do.....	4,850	do.....	6.00	7.35	May 4	109	4	3.7354	3.68
16	Wheat..	4,700	Deep uniform clay loam.....	6.00	7.35	June 30	39	3	.7579	<i>Bushels.</i> 24.66
17	do.....	4,700	do.....	5.16	7.35	June 27	35	3	1.3089	23.83
18	do.....	4,700	do.....	3.07	7.35	June 25	43	3	2.2844	31.59
19	Big "4" oats.	4,700	Deep uniform clay loam.....	4.73	7.35	June 8	58	3	.7833	41.22
20	do.....	4,700	do.....	4.80	7.35	June 6	47	3	1.2642	41.45
21	do.....	4,700	do.....	4.90	7.35	June 5	49	3	1.5722	41.22
22	Alfalfa..	4,300	Deep clay loam.....	3.82	7.35	May 26	74	3	1.3327	<i>Tons.</i> 3.94
23	do.....	4,300	do.....	3.61	7.35	May 7	95	4	2.3552	6.11
24	do.....	4,300	do.....	5.77	7.35	May 4	112	6	3.5394	6.10
25	Wheat..	4,850	Clay loam.....	4.96	7.35	June 27	13	2	.4737	<i>Bushels.</i> 12.29
26	do.....	4,850	do.....	4.36	7.35	June 24	17	2	.8890	17.20
27	do.....	4,850	do.....	4.83	7.35	June 21	19	2	.9253	13.72
28	Wheat..	4,300	Medium clay loam.....	3.92	7.35	June 7	25	2	.6553	33.17
29	do.....	4,300	do.....	4.19	7.35	June 4	40	3	1.3949	35.32
30	do.....	4,300	do.....	4.34	7.35	June 5	69	3	2.1856	32.25
31	Wheat..	4,300	Medium clay loam.....	3.19	7.35	June 28	17	2	.7080	32.28
32	do.....	4,300	do.....	3.18	7.35	June 27	18	2	1.0016	51.57
33	do.....	4,300	do.....	3.43	7.35	June 26	18	2	1.2413	46.80
34	Oats....	4,300	Medium clay loam.....	4.11	7.35	May 31	70	3	.6514	34.42
35	do.....	4,300	do.....	6.25	7.35	May 11	97	4	1.2835	44.88
36	do.....	4,300	do.....	2.27	7.35	May 28	72	4	1.6017	49.33
37	Wheat..	4,570	Deep uniform clay loam.....	7.05	7.86	June 24	.....	1	.4930	39.7
38	Oats....	4,570	do.....	2.38	7.86	June 25	.....	1	.7139	35.7
39	Sugar beets.	4,570	Uniform clay loam.....	7.83	7.86	Aug. 8	17	2	1.6432	<i>Tons.</i> 15.72
40	Oats....	4,570	Deep uniform clay loam.....	4.35	7.86	July 12	37	2	1.2930	<i>Bushels.</i> 33.3
41	do.....	4,570	do.....	4.57	7.86	July 16	34	2	1.7217	36.5
42	do.....	4,570	do.....	3.91	7.86	July 18	33	2	2.9109	16.6
43	Alfalfa..	4,700	Deep.....	3.58	7.86	May 26	.....	1	1.0440	<i>Tons.</i> 1.76
44	do.....	4,700	do.....	2.69	7.86	May 27	.....	1	1.5148	2.6
45	do.....	4,700	do.....	3.70	7.86	May 28	.....	1	1.8778	2.84

¹ Yield reduced by jack rabbits.

TABLE VIII.—*Effects of different volumes of water on grains, alfalfa, orchards, potatoes, and sugar beets during the season of 1913—Continued.*

No. of plot.	Kind of crop.	Altitude.	Class of soil.	Area.	Precipitation September, inclusive.	Date of first irrigation.	Length of irrigation season.	Number of irrigations.	Total depth irrigation water applied.	Yield per acre.
		<i>Fect.</i>		<i>Acres.</i>	<i>In.</i>		<i>Days.</i>		<i>Fect.</i>	<i>Tons.</i>
46	Alfalfa..	4,570	Deep uniform clay loam....	3.12	7.86	May 20	62	2	1.8571	3.9
47	..do....	4,570	..do....	2.82	7.86	May 18	63	2	1.7079	4.1
48	..do....	4,570	..do....	4.05	7.86	May 22	85	3	1.9375	3.89
49	Orchard	3,825	Medium clay loam	4.58	7.58	July 17	45	3	.3394	<i>Boxes.</i> 300
50	Wheat..	3,572	Uniform clay loam	.190	2.39	.....	.....	0	.00	<i>Pounds.</i> 0.00
51	..do....	3,572	..do....	.0873	2.39	June 3	.....	1	.2989	1,030.93
52	..do....	3,572	..do....	.0956	2.39	..do....	35	2	.5147	1,558.58
53	..do....	3,572	..do....	.0987	2.39	June 4	34	3	.5412	1,661.60
54	..do....	3,572	..do....	.0851	2.39	..do....	48	4	.9776	1,703.88
55	..do....	3,572	..do....	.0838	2.39	..do....	48	5	1.1816	1,551.31
56	..do....	3,572	..do....	.0945	2.39	June 5	53	9	1.8633	2,571.43
57	Wheat..	3,572	Uniform clay loam	.1925	2.39	.....	.....	0	.00	0.00
58	..do....	3,572	..do....	.0987	2.39	June 3	.....	1	.2644	1,109.42
59	..do....	3,572	..do....	.1033	2.39	June 4	34	2	.4749	1,839.30
60	Wheat..	3,572	Uniform clay loam	.0838	2.39	..do....	34	3	.6913	2,273.27
62	..do....	3,572	..do....	.0894	2.39	..do....	48	4	1.1846	1,879.19
63	..do....	3,572	..do....	.0945	2.39	..do....	48	5	1.2551	1,888.89
64	..do....	3,572	..do....	.1024	2.39	June 5	53	9	2.1977	3,632.81
65	Wheat..	3,572	Uniform clay loam	.1949	2.39	.....	.....	0	.00	0.00
66	..do....	3,572	..do....	.0851	2.39	June 3	.....	1	.2576	1,339.60
67	..do....	3,572	..do....	.0801	2.39	June 4	34	2	.4997	1,922.60
68	..do....	3,572	..do....	.0987	2.39	..do....	34	3	.6903	1,377.91
69	..do....	3,572	..do....	.0999	2.39	..do....	48	4	.9300	1,321.32
70	..do....	3,572	..do....	.0869	2.39	..do....	48	5	1.0969	2,531.65
71	..do....	3,572	..do....	.0765	2.39	June 5	53	9	1.8359	3,542.48
72	Barley..	3,572	Uniform clay loam	.6541	2.39	May 31	.....	1	.3902	2,057.79
73	..do....	3,572	..do....	.6938	2.39	May 30	24	2	.8168	1,948.69
74	..do....	3,572	..do....	.6019	2.39	..do....	36	3	1.4302	2,267.82
75	Barley..	3,572	Uniform clay loam	1.4073	2.39	May 1	49	2	1.3714	1,227.17
76	..do....	3,572	..do....	.7466	2.39	Apr. 30	90	3	2.6734	1,222.88
77	..do....	3,572	..do....	.7400	2.39	Apr. 29	90	5	2.7490	1,572.97
78	Oats....	3,572	Uniform clay loam	.9526	2.39	May 6	34	2	1.2858	1,709.10
79	..do....	3,572	..do....	.4943	2.39	May 7	80	3	1.6123	1,723.65
80	..do....	3,572	..do....	.4943	2.39	May 8	81	5	2.7353	2,120.17
81	Potatoes	3,572	Uniform clay loam	.644	2.39	July 12	.....	1	.793	12,251.55
82	..do....	3,572	..do....	.644	2.39	July 11	32	3	1.250	18,416.15
83	..do....	3,572	..do....	.618	2.39	July 10	49	6	3.127	22,095.47
84	Alfalfa..	3,572	Uniform clay loam	.4325	2.39	May 22	86	3	1.1763	10,601.16
85	..do....	3,572	..do....	.5271	2.39	May 21	87	4	1.8194	9,685.07
86	..do....	3,572	..do....	.4731	2.39	May 10	97	5	1.8468	10,410.06
87	..do....	3,572	..do....	.5032	2.39	May 9	98	7	1.9811	11,705.09
88	..do....	3,572	..do....	.4798	2.39	..do....	109	10	3.0548	13,989.16
89	..do....	3,572	..do....	.5372	2.39	May 8	118	13	3.3388	15,022.34

VARIATIONS IN IRRIGATION REQUIREMENTS OF SOILS.

A study of the results secured indicates that the porosity of the soil is one of the most important factors influencing the irrigation requirements of soils, and for the purpose of comparison the soils have been divided into two classes, according to their physical charac-

teristics: (1) The heavier soils, consisting of the clay, clay loams, sandy loam, and fine sandy soils; and (2) the porous soils, consisting of the coarse sandy and gravelly soils. The difference in the requirements of these two classes is illustrated by Table IX.

TABLE IX.—Average volumes of water used on tracts with different types of soil.

No.	Description.	Acre-feet used.		
		All soils.	Impervious soils.	Porous soils.
1	All tracts included in the investigation.....	12.06	11.60	4.66
2	All alfalfa tracts included in the investigation.....	3.35	2.40	7.10
3	All grain tracts included in the investigation.....	1.56	1.32	3.19

¹ Average low, due to fact that 74 per cent of tracts included was grain.

VARIATIONS IN IRRIGATION REQUIREMENTS OF CROPS.

Table X is made up from the data secured on the medium clay loam type of soils and shows, by crops, the average quantities applied to the majority of the tracts of this type included in the investigation.

TABLE X.—Average volumes of water applied to different crops on medium or clay loam soils.

No.	Kind of crop.	Number of plots.	Average volume of water applied per acre.
			<i>Acre-feet.</i>
1	Winter grain.....	15	0.82
2	Spring grain.....	216	1.27
3	Alfalfa.....	79	2.43
4	Pasture.....	13	13.02
5	Potatoes.....	17	1.71
6	Orchard.....	11	1.45

¹ Waste not deducted from volume applied to part of tracts included. Proper average quantity retained approximately 2.8 acre-feet.

Table X shows that different crops received different volumes of water and that for the purpose of comparison they may be safely divided into two classes—the winter and spring grains, potatoes, and orchards falling in one class and the alfalfa and pasture falling in the other. The table does not show the irrigation requirement for the various crops on this type of soil, for some of the experiments showed rather low yields, due to excessive or insufficient water.

In order to throw light upon the irrigation requirements of the two classes into which the crops observed may have been divided, the data have been combined in a different manner in Table XI. In this table the yields from the plots making the maximum yields from all experiments on clay loam soils, irrespective of the quantity of water applied, are compared with the average quantities applied and yields produced from all plots on the same type of soil.

TABLE XI.—*Comparison of volumes of water used on plots giving maximum yields and the average volumes used on all plots on clay loam soils during 4 years, 1910 to 1913, inclusive.*

Description of plots.	Number of plots.	Average volume of water applied per acre.	Average yield per acre.	Average yield per acre-foot of water.
Alfalfa:		<i>Acre-feet.</i>		
All plots included in investigation.....	79	2.40	4.91 tons.....	2.04 tons.
Plots making maximum yield in each experiment.	26	2.73	5.47 tons.....	2 tons.
Grain and cultivated crops:				
All plots included in investigation.....	221	1.33	36.38 bushels..	27.39 bushels.
Plots making maximum yield in each experiment.	60	1.74	44.92 bushels..	25.79 bushels.

Table XI shows that the average quantity required to produce the maximum yield of crops was greater than the average quantity applied to all tracts included in the investigation. All the results from the experiments on clay loam soils have been plotted as curves, the volume of water applied and the yield produced being the two factors considered.

Figure 3 shows both the individual and the average yields secured, and the quantities of water applied to some 207 fields of spring and winter grains. The yields upon soils that have been fertilized either with manure or by the plowing under of alfalfa sod have been plotted as triangles, while those upon ordinary or infertile soils have been plotted as small circles. The points representing both fertile and infertile soils are widely scattered, indicating that the results secured from any one plot can not be depended upon and that only an average of the results from a large number of experiments should be taken into consideration. The points representing each experiment have been connected by straight lines. The curves showing the average of results in both fertile and infertile soils have been constructed by averaging the points at which these lines crossed the vertical lines of the diagram. Owing to the many factors which may affect the size of the crop produced with any given quantity of water, as is indicated by the variation in the points upon which the curves are based, these curves will not definitely fix the size of the crop that can be produced on any particular tract. Each is based upon a large number of determinations, however, and shows within reasonable limits the results which may be expected from clay loam soils.

A comparison of the two curves shows that a much higher efficiency is almost invariably secured from the water when applied to fertile soil, and they both show that with either the yields may be expected to increase as the water applied is increased until as much as $1\frac{1}{2}$ feet per acre have been applied, after which the yields will tend to decrease with greater applications. These curves show a striking agreement with the results given in Table XI and would

seem to prove that on an average about $1\frac{1}{2}$ feet of water per acre are required for the maximum yield of grain on the average soil of Idaho.

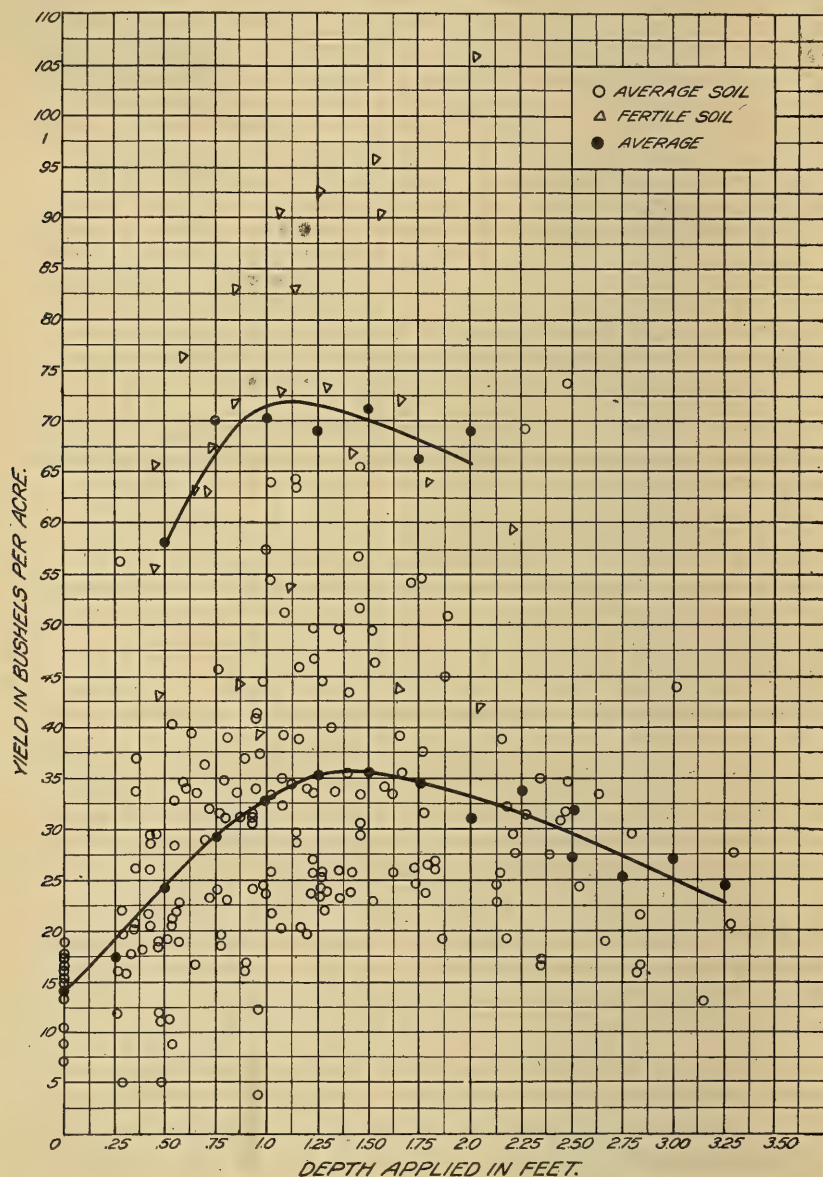


FIG. 3.—Irrigation requirement curve based on yields and amounts of water applied to 207 individual fields of grain on clay loam soils in Idaho during the seasons 1910 to 1913, inclusive.

The curve shown in figure 4 is made up from the results secured on 77 fields of alfalfa and clover on clay loam soil and shows marked tendency toward increase in yield as the application of water is in-

creased, as there is no appreciable break in the curve within the limit of the experiments. This curve shows again that alfalfa and clover require much larger supplies of water than grain, but the increase in the yield of alfalfa is not proportional to the increase in the water applied. Notwithstanding the fact shown by the curve, that the yield continues to increase with increased quantities of water, other considerations, such as the danger of water-logging land and the

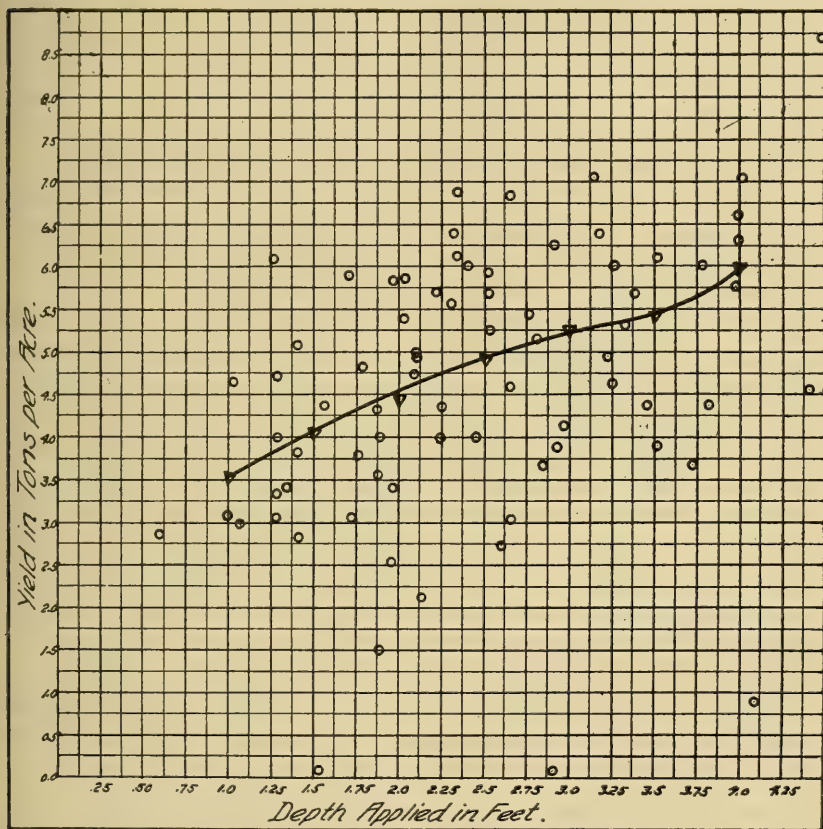


FIG. 4.—Curve based on yields and amount of water applied to 77 individual fields of alfalfa on clay loam soils in Idaho, during 5 seasons, 1910 to 1914.

limitation of the acreage which can be irrigated with a given water supply, would make it appear somewhat doubtful whether more than 3 feet per acre should ever be allotted to alfalfa on medium clay loam soil.

The alfalfa curve (fig. 4) was made up from observed data by first plotting all points on the sheet, after which points representing different plots of each experiment were connected up by straight lines similar to the method used with the grain curve (fig. 3). The depths

represented by the point where the various lines crossed each 0.5 foot in depth were then averaged, thus fixing the curve.

TABLE XII.—*Averages upon which alfalfa curve is based.*

Depth.	Number of points considered.	Average yield.	Depth.	Number of points considered.	Average yield.
<i>Feet.</i>			<i>Feet.</i>		
1.0.....	4	3.57	3.0.....	13	5.30
1.5.....	11	4.10	3.5.....	10	5.38
2.0.....	16	4.40	4.0.....	5	6.06
2.5.....	16	4.86	4.5.....	3	6.96

The curves in figures 3 and 4 show the average yields which were produced on the average clay loam soils of southern Idaho with given volumes of water, there having been a wide divergence in the results upon which they are based, and it should not be inferred that they will check exactly with the results from any individual farm.

The effect of fertility on the return of grain from the use of given quantities of water is illustrated further by an experiment which was carried on at the Twin Falls experiment station during the season of 1914. Six adjoining one-tenth-acre plots of rather infertile soil were planted to Marquis wheat. The land devoted to these plots had been farmed to grain six years after the sagebrush had been removed. Three of the plots were fertilized moderately, with applications at the rate of 15 loads of barnyard manure per acre; the remaining three were left in their original condition and did not receive any fertilizer. Two of the plots, one fertilized and one unfertilized, received an application of 1 foot of water per acre; the second two plots, one being unfertilized, received an average application of 2 feet per acre; and the third set of two plots, one of which was unfertilized, received an application of approximately 3 feet per acre. The results secured are shown in Table XIII.

TABLE XIII.—*Effect of fertilizer upon yield and irrigation requirements.*

No.	Method of treatment.	Area.	Number of irrigations.	Water applied per acre.	Yield of grain per acre.	Yield of grain per acre-foot of water applied.
		<i>Acres.</i>		<i>Feet.</i>	<i>Pounds.</i>	<i>Pounds.</i>
1	Unfertilized.....	0.094	3	1.05	1,000	952
2	do.....	.094	5	1.94	1,144	590
3	do.....	.094	7	2.99	1,266	423
4	Fertilized.....	.092	3	1.07	1,467	1,371
5	do.....	.092	5	2.01	1,663	827
6	do.....	.092	7	3.05	1,826	599

Results during the same season upon fertile alfalfa-sod ground 30 miles north of Twin Falls, at the Gooding experiment station, indi-

cated that the maximum yields were made with approximately 1 foot of water per acre, and that applications in addition to this quantity made a considerable decrease in the yield. There is no doubt that had the fertilized plots of the Gooding experiment been more fertile the largest yield would have been made with the 1 foot per acre.

This Gooding experiment, together with the other experiments which have been made, seems to prove conclusively that less water is required for the production of a given yield of crop on fertile soils than is required for the same yield of crop on infertile soils and emphasizes the necessity of maintaining a high state of fertility in cases where a high duty of water must be secured. It does not mean, however, that less water is required by the fertile soils, for, as shown by figure 3, fully as much is required for maximum crop production, a greatly increased yield being produced on the fertile soils.

RESULTS SECURED WITH INDIVIDUAL CROPS.

In order to show the results secured from single crops on the same type of soil, curves are shown in figures 5, 7, and 8. Each of these curves is based upon five years' results at the Gooding experiment station. The average amount of precipitation during the growing season for four of these five years was 2.92 inches. Considering that each of these curves is based upon a number of experiments, that this station lies at the average altitude for southern Idaho, and that the soil, which is a medium clay loam, rather impervious, and averaging 6 to 8 feet in depth, is representative, it is believed that the results plotted are typical of what may be expected throughout the State, and that they show within a reasonable limit the yield of crop which may be produced with a given quantity of water. These curves do not necessarily indicate a proper duty of water under good practice in Idaho, since, as is later stated, local economic features enter largely into all such problems.

The curves in figure 5 show the average results secured from 96 plots of staple varieties of spring wheat grown during the five seasons. One curve shows yields per acre, and the other yields per acre-foot of water applied. Considering the large number of plots upon which these curves are based, they should be very dependable. The curve showing yield per acre agrees with the data secured elsewhere throughout the State, in that it shows that the yield of grain will normally increase as the water applied is increased until an amount varying between 1.4 and 1.8 acre-feet per acre has been applied, after which the application of more water will decrease the yield of grain and in many cases the yield of straw as well (fig. 6). The curve showing yields per acre-foot of water (fig. 5) shows that the highest efficiency from water applied to spring grains is secured where the smaller quantities are

used. Where 2.8 feet per acre were applied each acre-foot gave a return of 584 pounds of grain, while an application of but 0.4 foot per acre yielded at the rate of 3,474 pounds per acre-foot, or very nearly six times as much grain per unit of water as was secured where the larger application was made. It must be noted, however, that the yield per acre with the application of but 0.4 foot per acre was rather

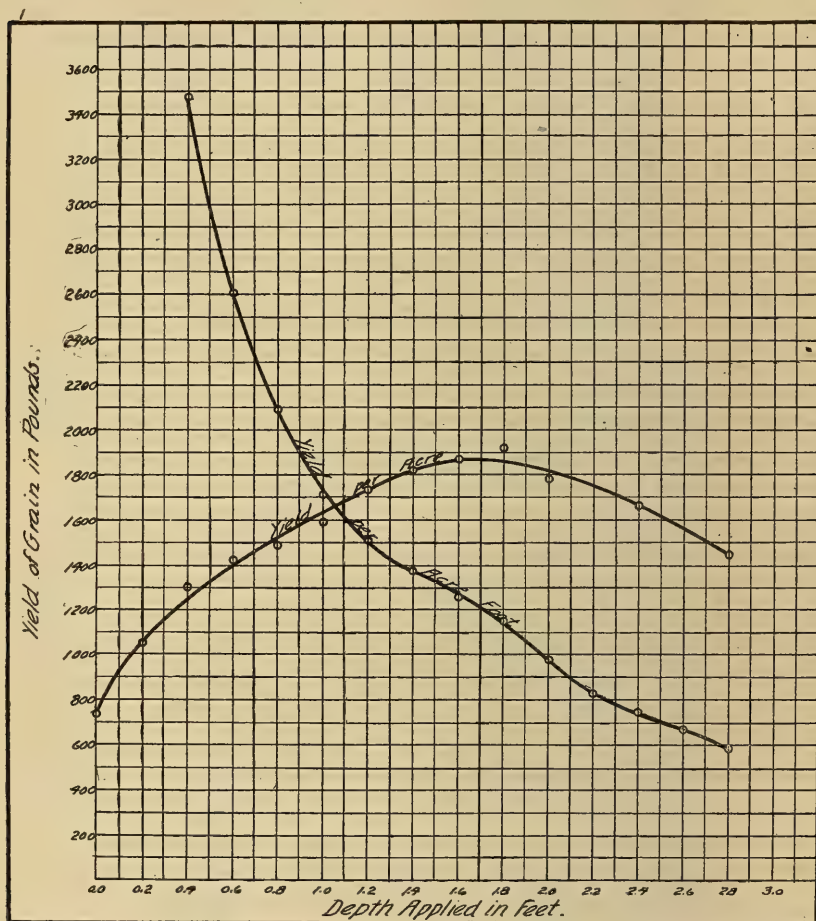


FIG. 5.—Yield per acre and per acre-foot of water applied from 96 plots of spring wheat at Gooding experiment station during five years, 1910 to 1914.

low and would not be profitable in many cases, because the returns would not equal the cost of production. While these two curves indicate the results which will be obtained by applying different volumes of water to spring wheat on this type of soil for the conditions obtained in southern Idaho, the economic quantity to allot for grain is a distinct problem. Whether it is more profitable to use little water per acre and get a large return per acre-foot of water and a low yield from the land, or to use more water and get a large return

per acre from the land and a low return per acre-foot of water depends on the relative cost of land and water, the cost of production, and other factors. The solution of the problem in each instance depends on local economic conditions.

The curves presented in figure 7 show the average results secured from 21 plots of alfalfa grown during five years at the Gooding experiment station, and also of three plots grown at Buhl, 30 miles away, on the same type of soil. These curves show that alfalfa requires large quantities of water and that the yield increases as the

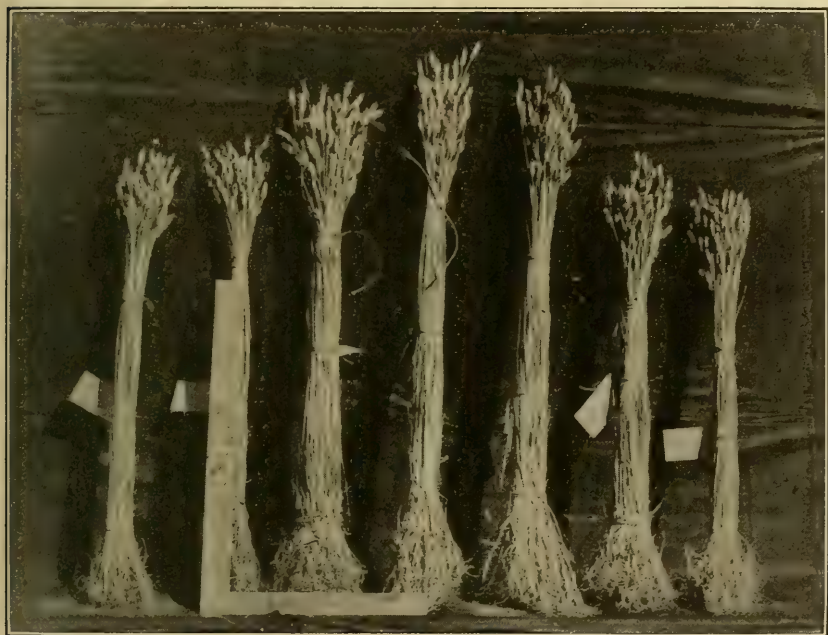


FIG. 6.—Effect of different amounts of water on the yield of straw. Gooding experiment station.

supply of water is increased, sufficient water not having been applied to determine at what point the excessive supply begins to decrease the yield of alfalfa. The lower curve shows yields of hay per acre-foot of water applied and indicates that while less efficiency is secured from water where large applications are made, the decrease is not nearly so pronounced as when they are applied to grain. These curves and the data from which they were constructed are typical of the results secured throughout other districts of Idaho on this same type of soil and show that if yield alone is considered it is difficult to apply too much water to alfalfa, provided no more is applied at one time than will be promptly absorbed by the soil. The proper quantity to allow for alfalfa, however, as with the grains, will be determined by local economic conditions.

The curves shown in figure 8 are made up from the results secured from 16 plots of potatoes grown at the Gooding experiment station during five years. The curves show that potatoes require somewhat more water than the grains and that there was a strong tendency for the yield to increase as the supply of water was increased within the limits of the experiment. Since the rate of increase in yield grows smaller as the quantity of water is increased, it probably will not be advisable or profitable to apply more than 2 or 2½ feet per acre to

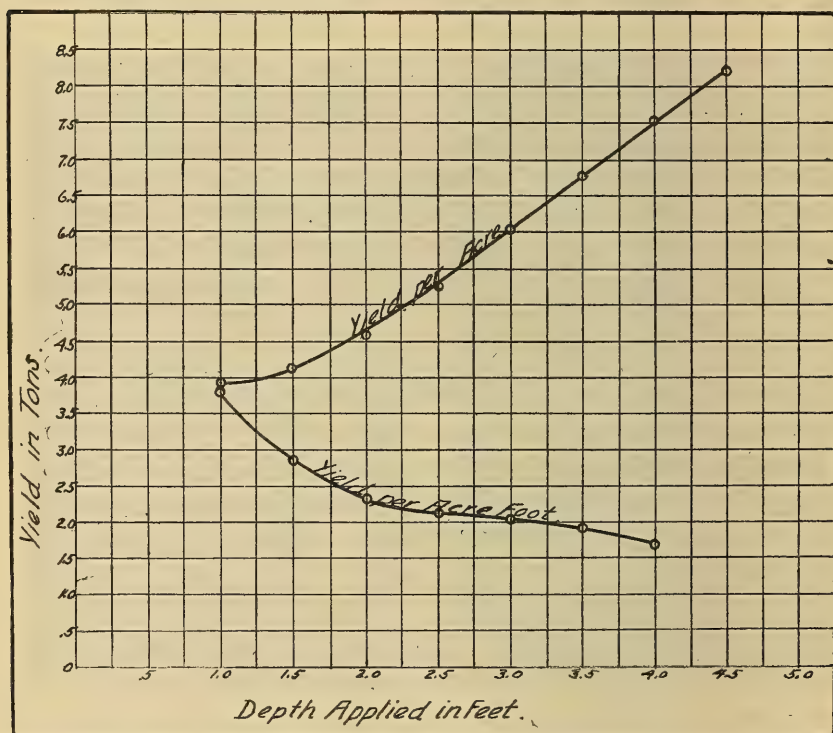


FIG. 7.—Yield per acre and per acre-foot of water applied from 24 plots of alfalfa at Buhl and Gooding during 5 years, 1910-1914.

potatoes on clay loam soil under conditions similar to those existing in the vicinity of Gooding. Here, as before, the curves indicate within reasonable limits the results which may be obtained with different volumes of water, and the quantity to apply in each case will be determined by local economic conditions.

IRRIGATION REQUIREMENTS AT DIFFERENT TIMES DURING THE SEASON.

The curves (figs. 5 and 7) do not show the proportion of the season's supply required at different times. In the design of irrigation projects, whether they be dependent upon reservoirs or direct diversion from

a stream, or whether water be pumped, it is necessary to know this factor. The irrigation requirements at different times throughout the season are controlled by the crops grown and the climate of the locality in question. Alfalfa or pasture in any arid region usually requires water throughout the growing season, or from early spring until late fall, while the grains require water during not to exceed the first one-half or two-thirds of the season. Potatoes require water throughout the season, but do not need it so early as grains.

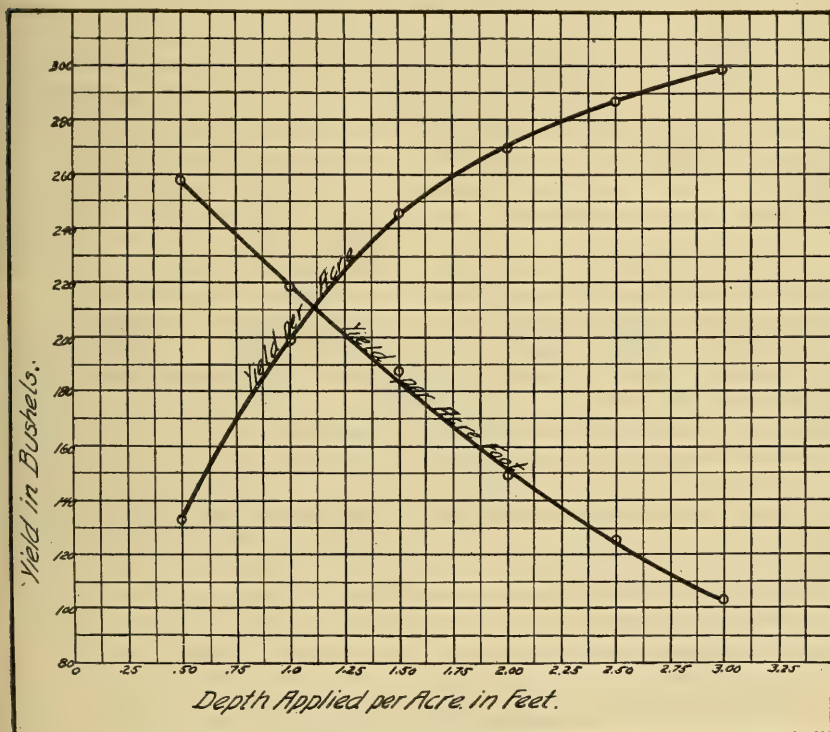


FIG. 8.—Yield per acre and per acre-foot of water applied from 16 plots of potatoes at Gooding experiment station during 5 years, 1910 to 1914.

Beets and orchards when well cultivated need little water in the early part of the season, the greater part of their requirements occurring from July to September, inclusive.

For the purpose of throwing more light upon the total requirements during the season and showing the proportion of the whole required during each month, the data secured from both the medium and porous soils have been reclassified in the following manner: (1) The data for each class of crop on each class of soil (for classes, see p. 20) have been segregated; (2) the average depths of water applied to the tracts for each month and for the season have been computed; and (3) tracts on which the yield was appreciably reduced by

deficient or excessive water application have been eliminated, as have a few tracts on which a very large increase in water application was necessary to produce a small increase in the yield. The remaining data, some 50 per cent of the original data secured, have been grouped in Tables XIV and XV.

TABLE XIV.—Average depths of water applied to 119 selected fields of grain and potatoes on medium clay and sandy loam soils, by months.

[Altitudes ranging from 2,400 to 5,000 feet.]

Season.	Number of plots.	Depth of water applied.					
		Apr. 16-30.	May.	June.	July.	August.	Total for season.
		<i>Foot.</i>	<i>Foot.</i>	<i>Foot.</i>	<i>Foot.</i>	<i>Foot.</i>	<i>Feet.</i>
1910.....	31		0.32	0.60	0.55	0.08	1.55
1911.....	30		.03	.65	.48	.01	1.17
1912.....	25			.94	.66	.05	1.65
1913.....	33	0.04	.21	.54	.59	.23	1.61
Average.....		.01	.14	.68	.57	.09	1.50
Per cent of total.....		.67	9.28	45.91	38.10	6.06	.....

Table XIV shows that both the months and the seasons have varied somewhat in their requirements and that the average annual requirement of water for this class of crop was 1.50 feet per acre. The results shown by the table are based upon the same data as are included in figures 5, 7, and 8, but were arrived at in a different manner. There is a very close agreement in that the requirement of water shown by the table is practically the same amount as that which the curves indicate will produce the maximum yield on both fertile and infertile soils.

Table XV shows the average depths of water used on alfalfa, arrived at in the same way.

TABLE XV.—Average depths of water applied to 52 selected fields of alfalfa and clover on medium clay and sandy loam soils.

[Altitudes ranging from 2,400 to 5,000 feet.]

Season.	Number of plots.	Depth of water applied.							
		April—		May.	June.	July.	August.	September.	Total for season.
		1-15.	16-30.						
		<i>Foot.</i>	<i>Foot.</i>	<i>Foot.</i>	<i>Foot.</i>	<i>Foot.</i>	<i>Foot.</i>	<i>Foot.</i>	<i>Feet.</i>
1910.....	15	0.06	0.02	0.55	0.74	0.65	0.61	0.07	2.70
1911.....	13		.04	.49	.29	.91	.70	.25	2.63
1912.....	11			.49	.50	.62	.61	.04	2.26
1913.....	13			.86	.25	.74	.39	.02	2.24
Average.....		.02	.02	.60	.44	.73	.58	.10	2.49
Per cent of total.....		.8	.8	24.1	17.7	29.3	23.3	4.0	.....

The average annual requirement of 2.49 feet of water per acre is less than the amount required to produce maximum yields, as shown by figures 4 and 7, where an application of 2½ feet produced yields of 5.25 and 4.86 tons per acre, respectively, with an increasing yield as the quantity applied was increased. The curves, however, do not show at what point economy demands that the quantity applied be fixed, and it is believed that the table does show this for economic conditions similar to those in Idaho.

The United States census of 1910 showed average yields of irrigated alfalfa as follows: Idaho, 3.27 tons per acre; Oregon, 3.29; Washington, 3.98; and California, 3.49, all other States having a less average yield. Considering these average yields along with the facts shown by both the table and the curves, and also the danger of water-logging the land and the curtailment of the State's irrigated area, it is believed that 2.5 feet of water per acre represents the proper allotment for alfalfa on clay loam soil under economic conditions similar to those of Idaho.

Each of Tables XIV and XV shows the monthly and seasonal requirements of only one class of crops. Hence, before the data contained in either or both of them may be used for the determination of the proper allotment on an entire project, it becomes necessary to know what crops will be grown upon the project, for alfalfa and pasture require so much more water than grains that the ultimate acreage of each particular class of crops becomes a dominant factor. In order to throw light upon this subject and furnish an accurate basis for combining the two tables to show the requirements of an entire project, a census of several typical Idaho irrigation projects was secured, the results being shown in Table XVI.

TABLE XVI.—*Areas devoted to different crops.*

District.	Year.	Hay and pasture.		Grain, potatoes, and orchard.		Total.
		Area.	Per cent of total.	Area.	Per cent of total.	
		<i>Acres.</i>		<i>Acres.</i>		<i>Acres.</i>
Twin Falls South Side project.....	1912	70,043	47.55	77,266	52.45	147,309
Do.....	1913	67,115	44.95	82,196	55.05	149,311
Seven Boise Valley projects.....	1911	126,253	59.75	17,684	40.25	43,937
Six Boise Valley projects.....	1912	24,492	57.90	17,804	42.10	42,296
Total.....		187,902		194,950		382,853
Average.....			49.08		50.92	

¹ This area and percentage was somewhat above normal on account of the comparatively large acreage of bottom land that was seeded to pasture under some of those canals.

Table XVI shows that under normal Idaho conditions almost exactly one-half of the irrigated acreage is devoted to each class into which the crops of the investigation have been divided. (See also p.

53.) As these were comparatively old, well-developed projects, and normal in every way, there is good reason to believe that the acreages of the different crops on other projects will bear practically the same relationship to one another in the future. If this is the case, and the normal project of the West is ultimately devoted to approximately equal acreages of (1) spring and winter grains, root crops, and orchards, and (2) alfalfa, clover, pastures, and crops requiring similar quantities of water, the requirements of the projects as a whole will be found by averaging the requirements of the two classes of crops. This has been done in Table XVII, each line of the table representing the requirement of one class during a single year of the investigation. The average given in the table therefore shows the combined requirements during each month of the irrigation season for the two classes of crops during the four years of the investigation, the process of averaging having neutralized and offset the eccentricities of irrigators and the individual differences of the seasons, stand of crop, soils, and plots included in the investigation.

TABLE XVII.—*Average depths of water applied to 171 selected fields of grain and alfalfa on medium clay and sandy loam soils.*

[Altitudes ranging from 2,400 to 5,000 feet.]

Crop.	Season.	Number of plots.	Depth of water applied.								Total for season.
			April—		May.	June.	July.	August.	September—		
			1-15	16-30					1-15	16-30	
			<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>	
Alfalfa.....	1910	15	0.06	0.02	0.55	0.74	0.65	0.61	0.07	2.70	
Grain.....	1910	31			.32	.60	.55	.08		1.55	
Alfalfa.....	1911	13		.04	.49	.29	.91	.70	.25	2.68	
Grain.....	1911	30			.03	.65	.48	.01		1.17	
Alfalfa.....	1912	11			.49	.50	.62	.61	.04	2.26	
Grain.....	1912	25				.94	.66	.05		1.65	
Alfalfa.....	1913	13			.86	.23	.74	.39	.02	2.24	
Grain.....	1913	33		.04	.21	.54	.59	.23		1.61	
Average.....			.01	.01	.37	.56	.65	.34	.04	1.98	
Per cent of total.....			.5	.5	18.7	28.3	32.8	17.2	2.0		

Table XVII is a general average of the results which have been secured on the average soil of southern Idaho during the entire four years' investigation, after eliminating the results secured from all tracts whose yield was reduced by excessive or insufficient application, and is considered by far the most important table included in this report. The facts given in the table are shown graphically in figure 9. It is in reality the meat, or final result, of the entire four years' study of water investigation, and as the soil in question is an average of that which is, or will be, included in at least 75 per cent of Idaho's irrigation projects, and probably of as large a per cent of the projects in many other States, it is believed

that this table may be used far more than the corresponding one (Table XVIII), which shows the average volumes of water applied to porous soils. As has been stated elsewhere in this report, the irrigation requirements of any particular crop on any soil are influenced by many factors and will be found to vary on different farms and during different years, but as this table includes the results of 171 selected tracts of this particular type of soil, covering a period of four years, thus effectually neutralizing the individual differences of

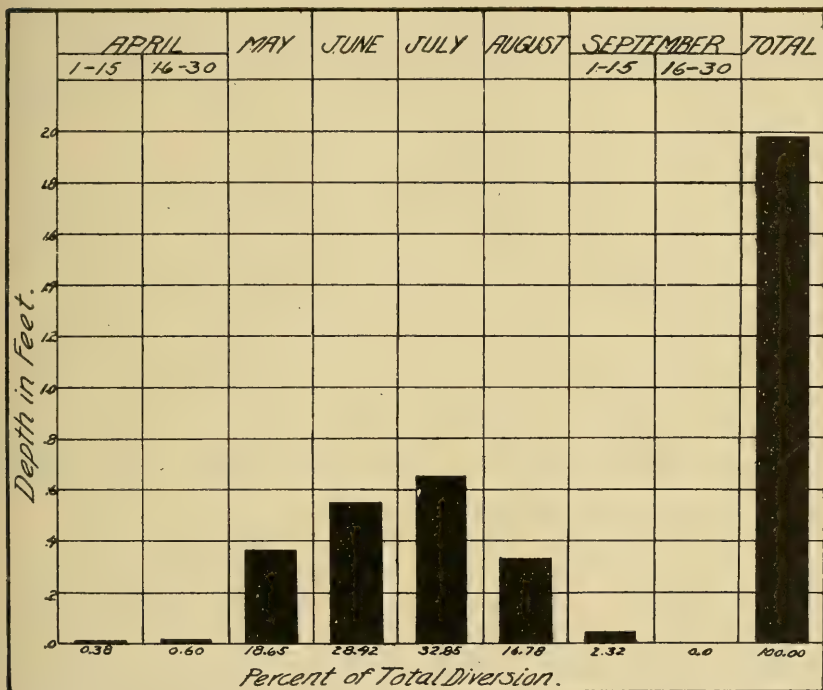


FIG. 9.—Amounts of water required each month of the irrigation season by an Idaho project devoted to equal areas of grain and hay on medium clay loam or sandy loam soil.

the seasons, of irrigators, and of the tracts themselves, it is considered that the results will be found to be very dependable.

Keeping in mind that the table shows averages only, and that individual crops, farms, projects, and seasons are bound to depart from the average, the table shows that a project devoted to equal areas of (1) grain, orchards, and general root crops, and (2) hay, including alfalfa, clover, timothy, and pasture, on average southern Idaho soil should furnish sufficient water so that an average of 2 feet can be retained on each and every irrigated acre during the season. Of this quantity, which is exclusive of the precipitation, 0.01 foot in depth, or 0.5 per cent, will be required during the first half of April;

0.01 foot in depth, or 0.5 per cent, will be required in the last half of April; 0.37 foot in depth, or 18.7 per cent, during May; 0.56 foot in depth, or 28.3 per cent, during June; 0.65 foot in depth, or 32.8 per cent, during July; 0.34 foot in depth, or 17.2 per cent, during August; and 0.04 foot in depth, or 2 per cent, during the first half of September, making a total of 1.98 acre-feet.

The above estimates are based strictly upon the crop needs, as shown by the irrigation-requirement investigation, and include nothing for stock water or that which may be required for domestic purposes, nor is there any included for waste from the fields or for late fall or winter irrigation. If the data in this table are to be used in allotting water to an irrigation project, and if the water is to be used for the above-mentioned purposes, these factors must be taken into consideration.

Table XVIII shows that there is small need for water earlier than May or later than August and that with all of the tracts considered there has been no need for water during the four years of the investigation by either alfalfa or grain during the last half of September. It shows also that over 60 per cent of the total water required during the season is required in the 61-day period covering June and July. The table will be found useful to those called upon to design storage projects, as a variety of curves can be worked up from it, which, taken in connection with the hydrograph of the discharge of the stream from which the supply is to be derived, will show how much of the water it will be necessary to store.

It also will be helpful in the designing of pumping plants, and particularly in determining the size of the various pumping units that should be installed. The table shows that any large pumping plant should consist of more than one unit, and possibly as many as three or four, for a unit that could economically supply the maximum demand during June and July could not possibly be operated economically with the decreased demands of May and August. This feature must always be given consideration.

The table seems to prove conclusively that the uniform continuous-flow method of delivery is exceedingly wasteful, for if a right called for a uniform continuous flow throughout the season with an allotment per acre of sufficient size to deliver the required amount during June and July, a large proportion of the quantity delivered could not be used economically and would be wasted during April, May, August, and September. While on the other hand, if the uniform continuous flow were of the size required to deliver the 2 acre-feet required during a six-months' or even a four-months' irrigation season, there still would be more water than is actually required during the early and late parts of the season and less than is actually required during

the months of June and July. Many instances have come to the attention of the writer where the advocates of a high duty have overlooked the unequal requirements of the different months of the season, and it is desired to emphasize the fact that this must not be ignored if the best use of the water is to be secured.

Table XVIII gives a general summary of the results that have been obtained upon porous, sandy, and gravelly soils. This table has been constructed by averaging the requirements of grain and alfalfa on these soils during the first two years of the investigation in the same manner used with the clay soils, there not having been a sufficient number of tracts of this type of soil experimented upon during the last two years of the investigation to be included in such a summary table.

TABLE XVIII.—Average depths of water applied to 21 selected fields of grain and alfalfa on porous, sandy, and gravelly soils.

[Altitudes ranging from 2,600 to 5,800 feet.]

Crop.	Season.	Number of plots.	Depth of water applied.								Total for season.
			April—		May.	June.	July.	August.	September—		
			1-15	16-30					1-15	16-30	
			<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>
Alfalfa.....	1910	7	.....	0.53	1.12	1.69	1.96	1.13	.....	.....	6.43
Grain.....	1910	10	.....	.....	.03	1.44	.66	.36	.....	.....	2.49
Alfalfa.....	1911	6	.....	.18	.92	1.84	1.12	2.27	0.26	.....	6.58
Grain.....	1911	8	.....	.....	.....	.90	1.06	.94	.....	.....	2.90
Average.....			.....	.18	.52	1.47	1.20	1.18	.06	.....	4.60
Per cent of total.....			.....	3.9	11.3	32.0	26.0	25.6	1.3	.....	.....

Table XVIII shows that porous soils require a larger supply of water for their efficient irrigation than the medium soils, the exact quantity required being governed by the porosity of the soil, the method of preparation, and the skill used in the application of the water. The results shown in this table indicate that an application of 4.6 feet to the acre per annum will be required for this type of soil, of which 3.9 per cent will be required during the last half of April; 11.3 per cent during the month of May; 30 per cent during June; 26 per cent during July; 25.6 per cent during August; and 1.3 per cent during the first half of September.

SURFACE WASTE.

The measurements just given do not include waste from irrigated lands. In the variation experiments the waste from the various plots was measured, with the results shown in Table XIX.

TABLE XIX.—*Percentage of total supply wasted from surface.*

Crop.	Class of soil.	Number of irrigations.	Percentage of waste.		
			Maximum.	Minimum.	Average.
Alfalfa.....	Clay loam.....	302	<i>Per cent.</i> 55.7	<i>Per cent.</i> 0.0	<i>Per cent.</i> 19.1
Grain.....	do.....	291	83.3	0.0	25.3
Alfalfa.....	Gravelly.....	147	24.8	0.0	1.8
Grain.....	do.....	122	31.4	0.0	2.3

Table XIX shows that over one-half of the water applied to grain and alfalfa upon clay loam soils is sometimes wasted, and that the average waste of the total quantity applied was 25.3 per cent for grain and 19.1 per cent for alfalfa. The above figures are based on the results from single fields, however, and irrigators should not be allowed to waste this percentage from their entire holdings. Irrigated farms should be so laid out that as much as possible of the waste water may be caught up and used over again on one or more fields before it is finally allowed to be wasted from the farm. It is safe to assume that the average farm could be so laid out that the water would not waste directly off the farm from over one-fourth its area. Rather steep farms, however, of small area, would suffer a larger waste than large farms or those with flatter slopes. Under normal Idaho conditions it is believed that all water contracts should provide for a sufficient delivery over and above the actual water requirements of the soils and crops so that the irrigator could waste between 7.5 and 12.5 per cent of the quantity delivered to him and still retain sufficient for his crop needs. The fact that present economic conditions will not justify a farmer in eliminating all waste must not be overlooked when designing new projects, and the contracts should provide for a delivery somewhat in excess of the actual needs of the soil and crops. This is not a serious factor when a project as a whole is considered, for at least one-half of the quantity wasted by the individual farmer can usually be caught up and measured out to other consumers.

DEEP PERCOLATION WASTE.

That crops do not and can not utilize at the most more than 2.5 acre-feet per annum and that they probably utilize and transpire far less than this amount has been proved by the many large yields that have been made in the Idaho investigation with comparatively small supplies of water, and may also be seen from the curves in figures 3 and 4. Much of the water applied in excess of 2 to 2½ feet per acre in any region is lost through evaporation, surface waste, or deep percolation. With the more porous soils the loss from deep percolation beyond the reach of the plant roots is the greatest source

of waste from the fields, as well as the hardest one to overcome. That large losses are experienced from this source is proved by the fact that the ground water under almost all irrigated projects rises rapidly, the rise being either a seasonal or a permanent one. Where excellent underdrainage exists the water level usually recedes during the winter or nonirrigation season, but drainage of some sort is ultimately found necessary in at least a portion of most projects.

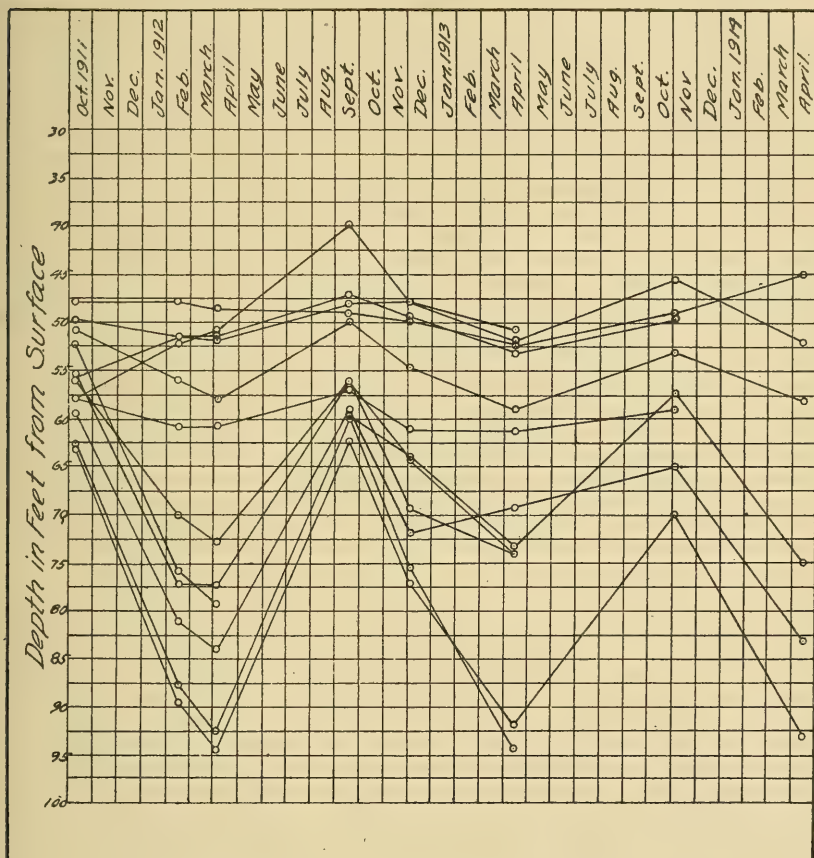


FIG. 10.—Variation in depth to water in wells in vicinity of Rigby, Idaho.

A typical case of the annual rise of water caused by deep percolation from porous irrigated land, there being excellent underdrainage from the land in question, is shown by the accompanying curves (fig. 10). These curves show the annual rise and fall of water in 13 wells in the vicinity of Rigby, Idaho, where there are 40,000 or 50,000 acres of porous irrigated land upon which large quantities of water are applied.

In order to demonstrate that a very large part of the irrigation water used in this locality was being lost by deep percolation, and to

show that light but rather frequent applications would give good results with these soils and that the application of water in this manner would result in a great saving of water, an experiment was carried on that it is believed has determined these factors in a satisfactory manner.

A water-tight galvanized-iron tank, 2 feet in diameter and 6 feet deep, with an outlet at the bottom terminating in a three-fourths inch galvanized-iron pipe 10 feet long, was installed in the soil flush with the surface of the ground. This tank was filled with 6 feet of soil in as near its original position as possible, three bands of hot asphaltum 1 foot wide were painted around the inside of the tank at 1-foot intervals to prevent percolation between the soil and the inside of the tank, after which the tank was irrigated each time an adjoining experimental plot was irrigated by applying the same amounts to the tank that were applied to the plot. Whatever water percolated through the 6 feet of soil in the tank drained out of the outlet pipe and was caught in a tub in a curbed pit 10 feet away. A total of 6.6 feet in depth in seven irrigations was applied to the experimental tract handled by the owner of the land and to the tank, and a quantity representing an equivalent of 5.5 feet per acre, or 83.5 per cent of the amount applied, percolated from the tank and was caught in the tub in the curbed pit, yet alfalfa which was planted on the tank when the experiment was started grew luxuriantly, demonstrating that the supply retained in the tank was adequate for the proper growth of the alfalfa. It was found that the tank during the season retained an average in its 6 feet of soil of 0.15 foot of water per acre for each application, and the experiment was continued during the following year, that of 1912, by irrigating the alfalfa in the tank whenever it appeared to require irrigation with 0.15 foot in depth at each application, no limit having been placed on the number of irrigations that were to be applied to the tank. It was found that the alfalfa in the tank required 10 irrigations during the season, and that there was but a trace of percolation from the tank. The alfalfa grown on the tank was cut, cured, and carefully weighed, and produced at the rate of 7.147 tons per acre, with an equivalent of 1.5 feet of water per acre plus a precipitation during the growing season of 8.51 inches. While this experiment was not conducted upon a scale broad enough to demonstrate the feasibility of this small amount of irrigation on large tracts or that this volume would produce the same comparative yield on them, it is believed, after taking into consideration the other observations, that it has been demonstrated that porous soils actually require but a very small supply at each application.

The securing of similar results from a practical application of the experiment just described requires a careful adaptation of methods of applying water to the types of soil to be irrigated. If an irrigation

system can be devised that will evenly apply a small quantity at each irrigation, porous soils can be irrigated and made to produce successful crops with no more water than is required for the irrigation of the medium or rather impervious soils.

NUMBER OF IRRIGATIONS TO APPLY.

The number of irrigations required during the season is dependent upon the soil, climate, and class of crop. Other things being equal, porous soils which have a low water-holding capacity and the very impervious soils which absorb only small quantities at each application, will require irrigation oftener than soils of the medium types. Alfalfa and pasture grow throughout a longer season than the grains and consequently require more irrigations. The number of irrigations required during the season may vary from 1 on winter grain in the high altitudes of Montana to as many as 20 on alfalfa in southern California and Arizona, if the same be planted on porous soils. The number of irrigations required under conditions similar to those of Idaho is approximately three for grain and five for alfalfa. The average number applied in this investigation on all types of soils was 3.1 for all grains and 5.4 for alfalfa. Clean-cultivated orchards on deep soils of medium texture will seldom require more than two or three irrigations per annum. A safe rule to follow for hay and pasture grasses is to apply a sufficient number of light irrigations during the season so that plants will not wilt for lack of water.

PROPER QUANTITY OF WATER TO APPLY AT EACH IRRIGATION.

A study of the tables included in this report shows that the volumes of water which have been applied to the various tracts at each irrigation have varied widely. It is not uncommon to find soils which are so impervious that they will absorb barely 0.1 to 0.15 foot in depth at each irrigation, or soils so porous that they can be made to absorb 1 to 3 feet in depth. The investigation has made it plain that a depth of 0.1 to 0.2 foot for one irrigation is insufficient if economy of water is desired, for the moisture forced into the soil does not last long enough, thus necessitating too many irrigations during the season. An unavoidable loss from evaporation invariably occurs during and immediately after each irrigation, and it is therefore desirable to apply as few irrigations during the season as will be required to maintain a sufficiently high moisture content in the soil for good plant growth. The investigation indicates that, generally speaking, from 3 to 6 acre-inches at one application is the correct quantity to apply and that impervious soils should be so manipulated that they can be made to absorb at least the smaller amount, while the porous soils should be so handled by using large irrigation heads that they can be

irrigated with not over 6 acre-inches at one application if economy of water is desired. It is hardly considered that it will ever be practical for the farmer to predetermine just how much should be applied at each irrigation and then apply this quantity and no more, but it is believed that intelligent and economical practice demands at least an approximate knowledge of the volume that is being applied. The fact that a head of 1 cubic foot per second delivers almost exactly 1 acre-inch per hour should make it comparatively easy for an irrigator to determine at least approximately how much water he applies to his land.

LENGTH OF IRRIGATION SEASON.

The length of the season during which crops require water depends upon both the climate and the crops grown. Grains require water for only a comparatively short season, winter grains frequently requiring but one irrigation, while alfalfa and pasture grasses require irrigation from early spring until late fall. The climatic conditions, with particular reference to the temperature, which determines the length of the growing season, have a very direct influence upon the length of the irrigation season, since the grass crops, provided an abnormal amount of natural precipitation does not occur, will require water for as long as the climate will permit them to grow. The length of the irrigation season in Idaho has been carefully determined by the investigation and is shown for the different crops by Table XX.

TABLE XX.—Average length of irrigation season of plots included in the 4 years' investigation.

Crop.	Year.	Total number of plots considered.	Average number of irrigations.	Number having 1 irrigation only.	Average length of irrigation season. ¹	Maximum length of irrigation season.	Average dates of irrigation.	
							First irrigation.	Last irrigation.
Grains.....	1910	76	3.6	3	<i>Days.</i> 46.0	<i>Days.</i> 87	May 27	July 12
Alfalfa and clover.....	1910	27	4.7	0	95.4	144	May 12	Aug. 12
Grains.....	1911	96	2.1	17	35.5	64	June 13	July 19
Alfalfa and clover.....	1911	34	6.1	1	111.4	142	May 14	Sept. 2
Grains.....	1912	60	3.7	10	39.7	61	June 9	July 13
Alfalfa and clover.....	1912	25	5.6	0	87.3	123	May 23	Aug. 18
Grains.....	1913	66	3.1	8	48.9	110	June 5	Aug. 20
Alfalfa and clover.....	1913	15	5.1	0	96.5	119	May 16	Do.

¹ Exclusive of plots having one irrigation only.

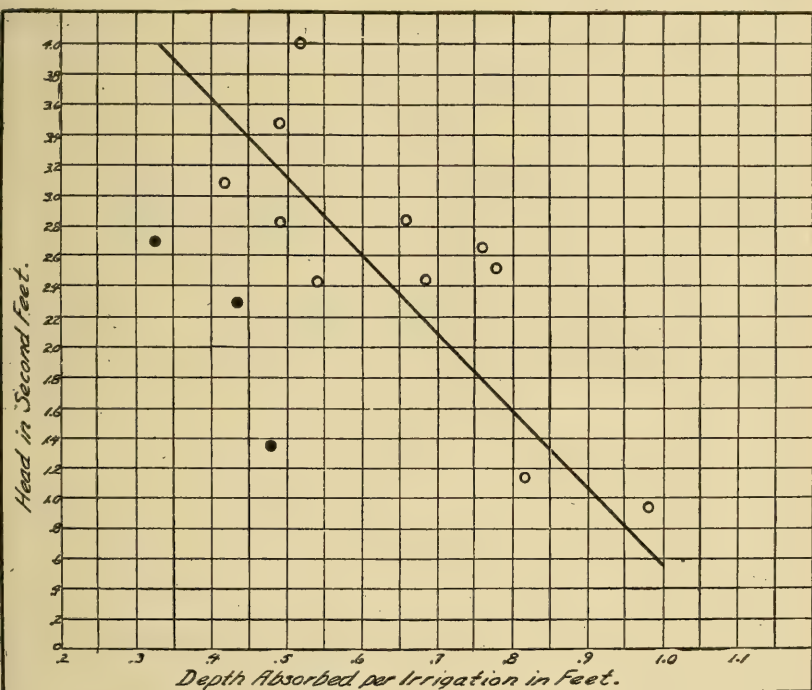
Average length of irrigation season for alfalfa for 4 years was 97.6 days.

Average length of irrigation season for grain for 4 years was 42.5 days.

SIZE OF IRRIGATION HEAD.

The size of the irrigation head used, particularly with the porous soils, has a great effect upon the irrigation requirements. It is a fact well known to irrigators who are accustomed to handling porous soils that very little can be accomplished with small heads of water for

the reason that the water is absorbed so rapidly that it can not be forced over the field. Where water can be conducted in pipes or tubes to within 100 or 200 feet of the farthest part of the field to which it is to be applied, a method common among southern California orange growers, large heads are not necessary, but where surface irrigation is practised on large field units of porous or semiporous soil, the use of large heads is imperative if economy of water is to be secured. The lack of efficiency of small irrigation heads was shown by several of the experiments which were included in the investiga-



● = Soil more moist than normal prior to these irrigations.

FIG. 11.—Effect of size of irrigation head upon amount required per application, based upon results of an experiment upon 4.3 acres of porous gravelly loam soil in Boise Valley planted to pasture.

ion. The average size of the irrigation head which is used for nearly all purposes in the larger portion of Idaho seldom exceeds 1 to 2 second-feet, yet the use of heads three or four times this size would give a much higher efficiency, particularly if the soil is inclined to be at all porous. With rather impervious soils there is not such a loss in efficiency. The smaller the size of the head and the greater the distance water is run the larger the irrigation requirement. The accompanying curve (fig. 11) based on an experiment conducted by V. G. Steward, of the Boise project, United States Reclamation Service, clearly indicates the saving that may be made by using large heads for the irrigation of porous soils.

LENGTH OF RUN.

Water never should be flooded too far between cross ditches on any crop or on any class of soil. An even application of water to all parts of a field is highly desirable but is very difficult to secure even with the best of systems in use. Where water is run too far between cross ditches there is either oversaturation and deep percolation loss on the upper end near the supply ditch, or insufficient absorption at the lower end near the waste ditch. This is particularly true with soils which absorb water readily. Other things being equal, water

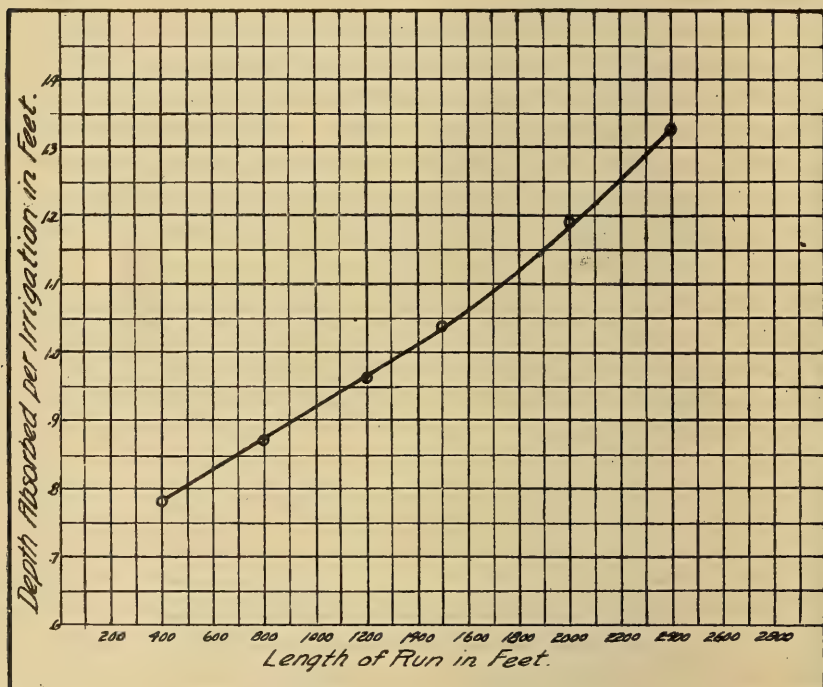


FIG. 12.—Effect of length of run upon amount required per application. (Based upon results from 20 different plots of porous soil.)

should be flooded shorter distances on porous soils than on the more impervious soils. Experiments conducted upon 20 plots of very porous soil in the vicinity of Rigby, Idaho, have demonstrated that a very great saving of water may be made by flooding shorter distances than is usual, and it is thought that a preparation of the land into narrower, shorter borders, and the use of larger heads would have resulted in a still greater saving. The curve in figure 12 is self-explanatory and clearly illustrates the great saving of water which may be made on porous soils similar to those near Rigby (Pl. II, fig. 2) by flooding water shorter distances.

FALL PLOWING.

An experiment was carried on at the Gooding experiment station to determine the effect of fall versus spring plowing on the duty of water and yield produced, with the results that are shown in Table XXI.

TABLE XXI.—*Results of fall versus spring plowing, Gooding experiment station.*

Sub-plot No.	Area.	Treatment of subplot.	Water applied per acre.	Yield of grain.		Weight of grain per bushel.
				Per acre.	Per acre-foot of water.	
	<i>Acre.</i>		<i>Acre-foot.</i>	<i>Bush.</i>	<i>Bush.</i>	<i>Pounds.</i>
1	0.314	Fall plowed, minimum irrigation.....	0.376	41.18	109.5	38
2	.315	Spring plowed, minimum irrigation.....	.376	32.88	87.5	38
3	.314	Fall plowed, average irrigation.....	.962	43.65	45.5	41
4	.314	Spring plowed, average irrigation.....	.962	39.77	41.4	41
5	.304	Fall plowed, maximum irrigation.....	1.533	47.54	31.0	42
6	.305	Spring plowed, maximum irrigation.....	1.533	45.26	29.5	42

A study of Table XXI makes it apparent that too much emphasis can hardly be placed on the many advantages of fall plowing.

MEASUREMENT OF WATER USED ON FARMS AND UNDER COMPLETE CANAL SYSTEMS.

It is believed that the supply of water has been varied upon a sufficient number of tracts in this investigation and that the investigation has covered a sufficient number of seasons to furnish a correct idea of the irrigation requirements of the soils and crops included, but as an investigation of this sort alone furnishes no information (1) of the water required for domestic purposes, (2) of the transmission losses and other general wastes, or (3) of the average use of water on typical Idaho farms when such use is unrestricted, it was thought best to investigate also the use of water both upon typical farms and under complete canal systems of the State. The investigation was therefore extended so as to include a careful measurement of the quantities used by a large number of typical farmers and by seven complete canal systems in 1911 and eight complete canal systems in 1912.

The water used on the farms investigated was measured by automatic water registers which were installed on weirs in the feed ditches leading to the tracts or farms in question. The type of water registers used and the method of their installation in connection with the weirs are shown in Plate III, figure 1.

The volume of water diverted and used by the canal systems was determined by daily gage readings and a large number of current-

meter determinations at the head of the main canal of each system (Pl. III, fig. 2). The gages were read by men employed for the purpose, and the discharge curves were based in each case upon 20 to 30 current-meter ratings which were made during the season at each station by two to six hydrographers with different meters. The areas irrigated under each system and the crops that were grown were determined by a house-to-house canvass of each farm.

BOISE VALLEY FARMS.

The quantity of water delivered to a total of 428.64 acres on 16 farms in the Boise Valley was determined during the season of 1912. The farms included were located in the heart of the valley, near Meridian, and represented typical Boise Valley conditions, and the average use of water at the individual farmer's head gates in the district during the season was found to be 2.56 feet per acre, the quantity wasted not having been deducted. Of the 428.64 acres included, 144.84 acres were devoted to alfalfa, pasture, and other hay grasses, the remainder to grains, potatoes, and orchards. The soil of the district is nearly uniform and consists of a clay loam 3 to 8 feet in depth, underlain with a rather compact gravel. The water for irrigation purposes in the above district is used with more than the average care, and the use of water shown by the measurements corresponds very closely with the requirements shown by the variation experiments.

SALMON RIVER PROJECT FARMS.

The water applied to a total of 978.22 acres on 12 farms of the Salmon River project was measured during the season of 1913, the area involved having all been determined by transit surveys. The soil of the district is a clay loam 2 to 6 feet in depth underlain by lava rock. The total area involved consisted of 200.73 acres of hay and pasture grasses, and 777.49 acres of grain, potatoes, and orchards, and the use of water by the farmers varied from 0.77 to 5.30 acre-feet and averaged 2.08 acre-feet for the entire area. This was the first year some of this land had been irrigated, and it is believed the 2.08 acre-feet, with one or two exceptions, represented the average use of water on the entire project at that time. The quantities wasted from these tracts were not measured.

WATER DIVERTED BY TYPICAL CANAL SYSTEMS.

The canal systems investigated in order to determine their head-gate diversions consisted of the Riverside, Farmers' Cooperative, Farmers' Union, Settlers', Boise Valley, Pioneer, and Eureka, typical canals of the Boise Valley; the Randall Canal, and the Clark and Edwards in the Upper Snake River Valley; and the South Side Twin Falls Canal, which irrigates approximately 200,000 acres on the

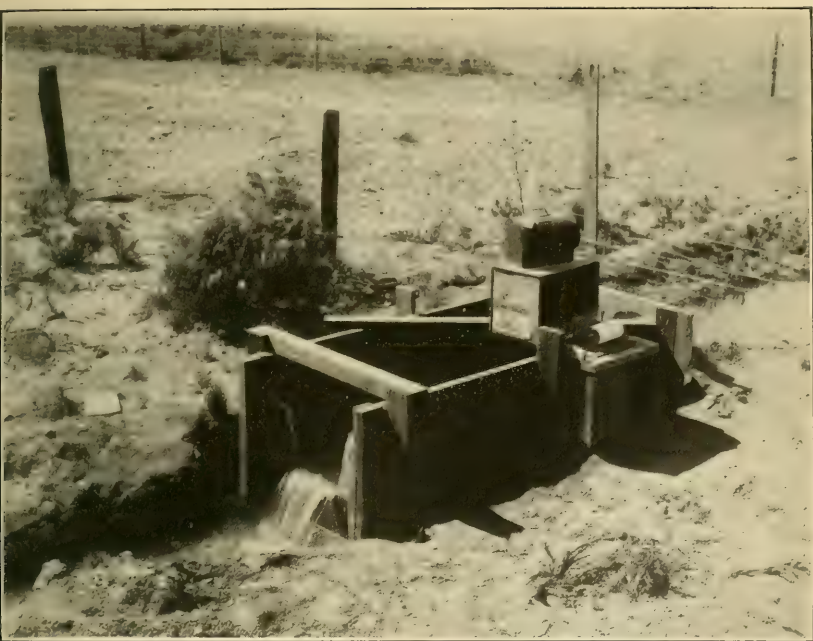
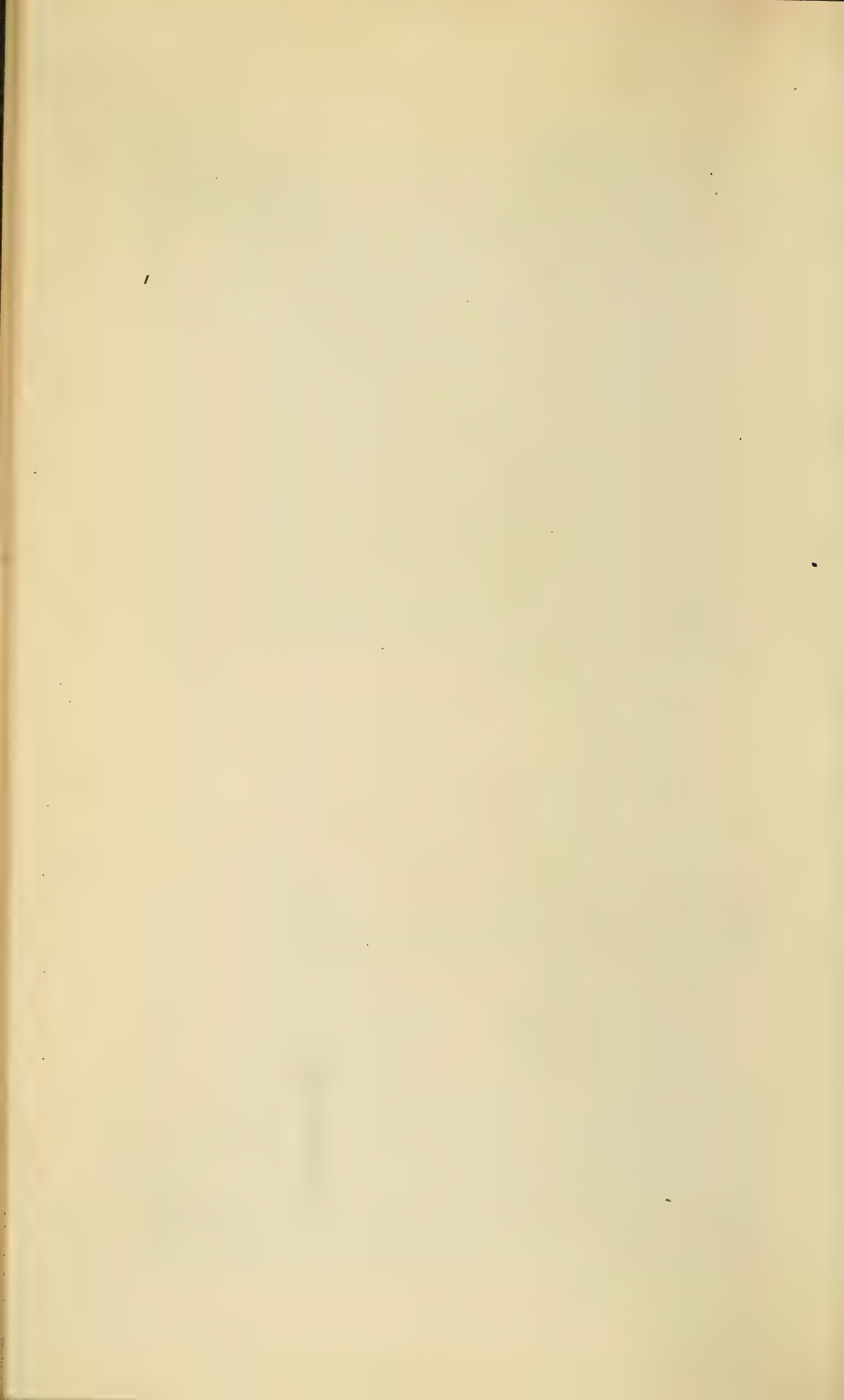


FIG. 1.—TYPE OF WATER REGISTER USED IN THE IDAHO INVESTIGATION, SHOWING THE METHOD OF INSTALLATION.



FIG. 2.—METHOD OF RATING LARGE CANALS.



south side of Snake River in Twin Falls County. Of the Boise Valley canals the Riverside, Farmers' Cooperative, Farmers' Union, and Settlers' irrigate clay loam bench soils almost exclusively, while the Boise Valley, Pioneer, and Eureka irrigate the more porous sandy loam and gravelly bottom soils. The ground water usually lies rather close to the surface under the lands irrigated by the bottom canals. The Randall and the Clark and Edwards canals irrigate very gravelly soil in the upper Snake River Valley, the gravel being of a very porous nature to a depth of at least 80 feet, at which depth the ground water is found. The South Side Twin Falls Canal irrigates approximately 200,000 acres of gently rolling clay loam soils with an average slope of about 50 feet per mile, the soil underlain with lava rock and ranging from 2 to 40 feet in depth, with a probable average of 8 feet. The data secured from these canal systems during the Idaho investigation are shown in a condensed form in tables XXII and XXIII, which follow. The volumes diverted by the canals during the season of 1911 were measured by W. G. Steward, of the United States Reclamation Service, and the remainder of the data was secured by our own assistants.

Table XXII shows areas devoted to different crops under the canals investigated:

TABLE XXII.—*Acreage devoted to different crops, and percentage of areas actually irrigated under ten different canals.*

Name of canal.	Year.	Hay.		Pasture.		Grain.		Orchard. ¹		Total.
		Acres.	Per cent.	Acres.	Per cent.	Acres.	Per cent.	Acres.	Per cent.	
Riverside.....	1911	4,059.00	54.7	175.25	2.4	911.00	12.2	2,280.25	30.7	7,425.50
Do.....	1912	3,455.75	50.1	627.25	9.1	1,360.00	19.7	1,455.50	21.1	6,898.50
Farmers' Cooperative.....	1911	5,526.75	44.4	1,626.00	13.1	2,043.50	16.4	3,239.00	26.1	12,435.25
Do.....	1912	4,890.00	37.4	2,289.50	17.5	2,354.25	18.0	3,528.66	27.1	13,062.41
Farmers' Union.....	1911	3,339.44	48.8	1,171.94	17.1	1,526.94	22.3	804.33	11.8	6,842.70
Do.....	1912	3,045.35	42.6	1,534.74	21.5	1,737.00	24.3	827.33	11.6	7,144.42
Settlers'.....	1911	4,385.25	37.1	2,157.25	18.2	3,686.50	31.2	1,590.80	13.5	11,819.80
Do.....	1912	4,490.25	38.2	1,848.20	15.7	3,294.75	28.0	2,121.80	18.1	11,755.00
Boise Valley.....	1911	332.25	14.9	1,189.09	53.4	277.80	12.5	426.35	19.2	2,255.49
Do.....	1912	267.00	11.7	1,222.50	53.4	336.00	14.7	461.50	20.2	2,287.00
Eureka.....	1911	369.00	17.9	1,138.75	55.2	505.00	24.5	49.25	2.4	2,062.00
Pioneer.....	1911	115.25	10.2	667.67	59.3	197.90	17.6	145.72	12.9	1,126.54
Do.....	1912	132.50	11.5	689.32	60.0	166.75	14.5	160.17	14.0	1,148.74
Randall.....	1912	1,193.50	36.6	207.50	6.4	1,145.00	35.2	709.00	21.8	3,255.00
Clark and Edwards.....	1912	570.00	41.9	97.00	7.1	463.50	34.0	232.00	17.0	1,362.50
South Side Twin Falls.....	1912	59,229.00	40.2	10,094.00	6.8	56,379.00	38.3	21,607.00	14.7	147,309.00
Do.....	1913	54,903.00	36.8	12,212.00	8.2	60,805.00	40.7	21,391.00	14.3	149,311.00
Total.....		150,303.29		38,947.96		137,189.89		61,029.71		387,470.85
Average per cent.....			38.8		10.1		35.4		15.7	100.00

¹ Includes small fruits, garden, potatoes, and home grounds.

Table XXII includes no uncleared land, but only the areas actually irrigated under each canal system investigated, and shows that 38.8 per cent of the area was devoted to hay, 10.1 per cent to pasture, 35.4 per cent to grain, and 15.7 per cent to orchard and miscellaneous

crops. The table confirms the conclusion reached from Table X, that normal projects are about equally divided between (1) hay and pasture and (2) grain and other miscellaneous crops.

The number of acre-feet diverted each month by each system was determined and computed, and Table XXIII shows the number of acre-feet diverted for each acre irrigated during each month of each season.

TABLE XXIII.—Quantity of water diverted for each acre irrigated during each month of irrigation season for ten different canals.

Name of canal.	Year.	Acre-feet diverted for each acre irrigated.									Total.
		April—		May.	June.	July.	Aug- ust.	Sep- tem- ber.	October—		
		1-15	16-30						1-15	16-31	
Riverside.....	1911	0.08	0.43	1.40	1.46	1.54	0.79	0.79	0.50	0.15	7.14
Do.....	1912	.11	.63	1.74	1.98	1.99	1.19	1.23	.62	.00	9.49
Farmers' cooperative.....	1911	.04	.38	1.31	1.36	1.16	.44	.36	.28	.19	5.52
Do.....	1912	.00	.08	1.07	1.26	.94	.58	.56	.17	.10	4.76
Farmers' Union.....	1911	.14	.48	1.25	1.41	1.25	.55	.45	.13	.00	5.66
Do.....	1912	.25	.68	1.32	1.23	1.07	.53	.45	.00	.00	5.53
Settlers'.....	1911	.04	.16	.42	.72	.71	.46	.42	.11	.00	3.04
Do.....	1912	.00	.01	.49	.69	.70	.54	.34	.10	.00	2.87
Boise Valley.....	1911	.14	.27	.63	.59	.64	.42	.30	.12	.00	3.11
Do.....	1912	.00	.00	.46	.50	.68	.38	.37	.00	.00	2.39
Eureka.....	1911	.00	.05	.38	.33	.34	.35	.34	.03	.02	1.84
Pioneer.....	1911	.11	.40	.91	.97	1.09	1.01	.83	.12	.00	5.44
Do.....	1912	.14	.00	1.12	1.62	1.03	.98	.82	.31	.00	6.02
Randall.....	1912	.00	.00	.00	1.58	2.25	1.99	.81	.25	.00	6.88
Clark and Edwards.....	1912	.00	.00	.31	2.59	3.00	2.67	2.04	.34	.00	10.95
South Side Twin Falls.....	1912	.10	.14	.60	1.10	1.23	1.13	.61	.22	.16	5.29
Do.....	1913	.09	.11	.83	1.12	1.25	1.21	.73	.20	.17	5.71
Average for month.....		.08	.22	.84	1.21	1.23	.89	.67	.20	.05	5.39
Per cent of season's diver- sion.....		1.49	4.08	15.6	22.43	22.83	16.5	12.43	3.71	.93	100.00

The investigation has demonstrated the adequacy of 2 acre-feet (p. 32) for diversified crops on clay loam soils, provided there is no waste, and the measurements of the use of water by the farmers in typical districts show that more than 2.5 feet per acre is seldom delivered to or used upon the land. The quantities diverted by the above projects, however, which represent the normal use in Idaho, show that they divert much more than is required for the crops on the farm. A comparison of these diversions with the quantities required and used on the farms would indicate (1) that water is wasted by the canal systems both early and late in the season; (2) that a considerable supply is required for domestic purposes and stock water; and (3) that the losses from seepage and evaporation in transmission, and from careless use, must be far larger than many have realized. The quantities shown as having been diverted per acre in the preceding tables are known to be very nearly accurate, and, considering the fact that it has been found necessary to divert these quantities under normal Idaho conditions, these data must be given careful consideration when designing projects with scanty water supplies.

SEEPAGE INVESTIGATION.

The losses to which the waters of an irrigation project are subject in passing from the point of diversion to the land to be irrigated have not always been given sufficient consideration in the designing of projects. It became evident early in the investigation that the losses to which canals in different types of soil are subjected should be measured in order to determine how much water should be diverted to deliver the quantity required. During the years 1912 and 1913, 118 sections of Idaho canals were measured for the determination of the seepage losses. These canals varied in discharge from 0.07 cubic foot per second to over 3,190 cubic feet per second, and in cross section from 0.117 square foot to 984 square feet. A total of 287.31 linear miles was included, covering all of the common soil types of Idaho, and it is believed sufficient data have been secured to furnish a substantial basis for estimating the losses to which the canals of this State will be subject.

METHOD OF INVESTIGATION.

All canals included in the investigation with a discharge of 3 second-feet and less were measured with Cipolletti weirs installed at the upper and lower ends of each section. The head on these weirs was read to the nearest 0.001 foot with small inexpensive hook gages that were especially designed for the purpose. All canals with a greater discharge than 3 second-feet were measured with current meters. The 0.2, 0.6, and 0.8, or 3-point, method of measurement was used in all cases where the canal exceeded 1 foot in depth, and either the 0.6, or integration, method with the shallower canals. In order to eliminate errors in computation, individual characteristics of the meters, and personal equation of the men, every section measured with current meters was measured by at least two hydrographers, each with a different meter, thus furnishing a double check on all results. It was found that fluctuations of gage height and discharge were the most troublesome factor in connection with seepage determinations, and the following method was used for the elimination of the effect of the fluctuations:

Canals to be included in the investigation were thoroughly looked over before any ratings were made, and gages which could be read to the nearest 0.02 foot were installed approximately every 2 miles in the main canal and at the head of all diversions, care being used to pick good sections in the middle or in the lower third of as long a tangent as possible. Discharge curves were plotted for each station by using the bottom of the canal as the zero or point of no flow, and the point at which water stood when the measurement was made as the only other point that was determined for each curve, care

being used to make them conform as nearly as possible to standard curves for similar sections. After all of the measurements had been made, floats consisting of tightly corked bottles were dropped into the main canal at the upper gage, and a man proceeded down with them, reading each gage in the main canal and at the head of all diversions at the time the floats passed. Other men with more floats followed the first ones at 2 to 3 hour intervals during the day. The discharges at the different stations and the consequent seepage losses between were determined from the gage heights at the time the floats passed, thus minimizing error from fluctuations in gage height. This method compares losses from the same flow or wave of water for a 12 or 14 hour period, and while the rating curves based on only two points may be slightly inaccurate, the canals were held quite uniform throughout the entire investigation.

The larger canals were measured either from cars which were suspended from cables across the stream or from a boat especially fitted up for the purpose (Pl. III, fig. 2). The smaller canals, where convenient bridges could be found, were rated from the bridges, and in other cases, where the depth permitted, wading measurements were made.

There are two common methods of expressing seepage losses. One is per cent of flow lost per mile, and the other the number of cubic feet lost from each square foot of wetted canal bed in 24 hours. The former and older method is more readily calculated and understood, but since the percentage decreases rapidly as the capacity is increased, many prefer the use of the latter unit, as it is more constant for any type of soil and largely independent of the capacity of the canal. Table XXIV gives the results of measurements of seepage losses. For convenience, the losses are expressed by both methods.

TABLE XXIV.—*Seepage losses from canals.*

No.	Average width of water surface.	Area water surface.	Wetted perimeter.	Discharge at upper end of section.	Total loss in section.	Length of section observed.	Loss per mile.	Loss per square foot wetted area per 24 hours.	Loss per mile.	Remarks.
	<i>Feet.</i>	<i>Square feet.</i>	<i>Feet.</i>	<i>Second-feet.</i>	<i>Second-feet.</i>	<i>Miles.</i>	<i>Second-feet.</i>	<i>Cubic feet.</i>	<i>Per cent.</i>	
1	0.9	0.12	1.0	0.07	0.02	0.490	0.04	0.666	57.1	Medium clay loam.
2	1.0	.16	1.2	.14	.02	.399	.05	.684	35.7	Do.
3	1.4	.19	1.5	.20	.04	.700	.06	.623	30.0	Deep clay loam.
4	1.5	.32	1.7	.28	.08	.682	.12	1.129	42.9	Clay loam, gravel.
5	1.5	.42	1.8	.36	.08	.379	.21	1.919	58.3	Do.
6	1.5	.48	1.9	.53	.07	.714	.10	.844	18.9	Clay loam, hardpan.
7	1.0	.28	1.4	.54	.07	.740	.10	1.107	18.5	Deep medium clay loam.
8	1.5	.22	1.6	.58	.03	.378	.08	.811	13.8	Shallow clay loam.
9	1.8	.45	2.3	.68	.03	.469	.06	.455	8.8	Impervious clay loam.
10	1.9	.43	2.1	.80	.13	.528	.25	1.919	31.3	Medium clay loam.
11	1.5	.35	1.7	.84	.03	.422	.01	.659	4.3	Do.
12	1.5	.52	2.2	.85	.12	.435	.28	2.052	32.9	Porous medium clay loam.
13	1.3	.36	1.6	.87	.04	.573	.07	.714	8.0	Deep clay loam.
14	3.5	.96	3.7	.99	.07	.519	.14	.596	14.1	Clay loam, hardpan.

TABLE XXIV.—*Seepage losses from canals*—Continued.

No.	Average width of water surface.	Area water surface.	Wetted perim-eter.	Dis-charge at upper end of sec-tion.	Total loss in sec-tion.	Length of sec-tion ob-served.	Loss per mile.	Loss per square foot wetted area per 24 hours.	Loss per mile.	Remarks.
	<i>Feet.</i>	<i>Square feet.</i>	<i>Feet.</i>	<i>Second-feet.</i>	<i>Second-feet.</i>	<i>Miles.</i>	<i>Second-feet.</i>	<i>Cubic feet.</i>	<i>Per cent.</i>	
15	1.8	0.52	2.1	1.12	0.10	0.480	0.21	1.623	19.8	Porous clay loam, hardpan.
16	2.5	1.0	2.9	1.22	.10	1.534	.06	.368	4.9	Impervious clay loam.
17	2.0	.58	2.3	1.28	.01	.351	.03	.203	2.3	Uniform clay loam.
18	4.3	1.2	4.6	1.28	.09	1.623	.06	.191	4.7	Impervious clay loam.
19	1.8	.72	2.6	1.41	.12	.316	.38	2.390	27.0	Porous clay loam.
20	3.6	1.2	4.0	1.45	.56	5.254	.11	.436	7.6	Clay and sandy loam.
21	3.4	.78	3.9	1.48	.13	.553	.24	.986	16.2	Clay loam, shale bottom.
22	3.0	2.6	4.0	1.91	.36	.662	.54	2.225	28.3	Sandy loam.
23	2.4	.82	2.8	2.0	.26	.945	.28	1.608	14.0	Clay loam, hardpan.
24	3.0	1.4	3.9	2.0	.23	.352	.65	2.742	32.5	Limestone shale bottom.
25	2.2	1.1	3.2	2.1	.10	.420	.24	1.218	11.4	Compact impervious clay.
26	3.0	.92	3.3	2.2	.05	.554	.09	.448	4.1	Shallow clay loam.
27	2.4	.91	2.8	2.2	.06	.659	.09	.532	4.1	Medium clay loam, hardpan.
28	2.5	1.1	3.0	2.3	.10	.576	.17	.947	7.4	Medium clay loam.
29	5.4	3.7	6.0	3.8	.18	1.175	.15	.418	3.9	Sandy loam and gravel.
30	7.9	5.0	8.3	4.5	.44	2.020	.22	.429	4.9	Impervious clay loam.
31	6.4	2.4	6.5	5.2	.21	2.650	.08	.184	1.5	Do.
32	8.3	6.1	8.8	5.4	.88	1.980	.44	.826	8.1	Porous clay loam.
33	7.5	4.6	7.9	6.2	.49	2.010	.24	.505	3.9	Clay loam, compacted.
34	3.9	3.6	5.5	5.4	.96	.498	1.93	5.735	35.7	Very porous gravel.
35	4.6	4.4	5.8	6.1	.46	.584	.79	2.222	13.0	Do.
36	7.7	4.6	8.0	6.8	.84	1.984	.42	.868	6.2	Clay loam, some rock.
37	8.6	5.0	8.8	7.1	.50	3.944	.13	.236	1.8	Impervious clay loam.
38	8.1	4.3	8.4	7.2	.38	1.460	.26	.507	3.6	Sandy clay loam.
39	7.3	4.6	7.8	7.8	.17	1.950	.09	.183	1.2	Shallow clay loam.
40	9.8	5.0	10.5	8.1	.54	3.010	.18	.280	2.2	Clay loam.
41	7.5	6.3	8.0	8.9	.85	.520	1.64	3.344	18.4	Medium gravel.
42	8.8	5.0	9.1	9.6	.46	1.968	.23	.420	2.4	Clay loam, silt.
43	9.7	5.0	10.0	10.0	.17	2.560	.07	.109	.7	Do.
44	13.3	7.3	14.1	10.8	1.18	3.000	.39	.456	2.8	Clay loam, rock.
45	5.8	7.9	7.5	11.1	1.15	1.790	.64	1.402	5.8	Uniform clay loam.
46	7.2	10.3	9.2	12.5	1.57	1.255	1.25	2.225	10.0	Medium gravel.
47	9.5	9.4	10.1	13.2	.94	1.309	.72	1.163	5.5	Gravelly clay loam.
48	11.9	9.6	12.8	13.3	1.14	1.970	.58	.690	4.4	Deep clay loam.
49	11.1	7.1	12.0	14.7	3.5	2.612	1.34	1.827	9.1	Deep sandy loam.
50	9.6	8.0	10.3	15.2	-1.52	1.780	.85	-----	5.6	Irrigated land above.
51	6.3	5.9	7.3	17.0	.87	1.840	.47	1.061	2.8	Compact clay loam.
52	8.6	11.6	9.9	18.5	1.35	.674	2.0	3.311	10.8	Medium gravel.
53	8.3	11.1	9.9	19.0	1.84	3.680	.50	.801	2.6	Impervious clay loam.
54	10.3	10.0	11.2	19.3	1.81	4.568	.40	.579	2.1	Gravelly clay loam.
55	11.2	11.0	11.7	21.7	2.3	3.812	.60	.876	2.8	Clay loam, silt.
56	10.8	10.2	11.5	22.1	2.5	1.830	1.37	1.944	6.2	Heavy sandy clay loam.
57	20.4	16.5	21.4	24.0	5.0	1.936	2.6	1.975	10.8	Sandy loam.
58	12.2	16.8	13.2	24.2	1.11	.478	2.3	2.879	9.5	Very gravelly.
59	27.3	32.2	28.2	31.2	1.43	3.770	.38	.220	1.2	Deep clay loam, silt.
60	8.9	13.0	11.2	41.1	4.8	3.171	1.51	2.212	3.8	Very gravelly.
61	29.5	27.0	30.0	43.0	5.0	2.210	2.3	1.234	5.3	Hardpan, shale.
62	19.8	28.7	20.8	43.6	1.35	1.881	.72	.565	1.7	Deep clay loam.
63	19.7	31.1	20.8	45.5	1.90	1.746	1.09	.856	2.4	Do.
64	19.5	33.4	20.6	50.3	4.8	3.000	1.60	1.271	3.2	Do.
65	26.9	29.2	26.6	54.2	2.4	3.320	.72	.445	1.3	Gravelly hillside.
66	21.7	39.8	22.7	59.0	8.7	4.533	1.92	1.384	3.3	Deep clay loam.
67	24.4	39.8	25.5	68.1	.76	3.140	.24	1.553	3.4	Shallow clay loam.
68	24.8	52.7	25.9	73.0	14.0	4.862	2.9	1.819	4.0	Deep clay loam.
69	12.5	27.6	15.2	77.0	1.44	1.660	.87	.934	1.1	Impervious clay loam.
70	45.0	58.3	46.3	78.6	5.9	2.928	2.0	.712	2.5	Medium clay loam.
71	30.0	43.5	30.5	79.5	2.9	3.320	.87	.469	1.1	Gravelly sidehill.
72	14.8	30.8	17.4	91.5	2.2	1.570	1.40	1.317	1.5	Uniform clay loam.
73	23.3	45.8	24.5	92.2	3.4	3.138	1.08	.724	1.2	Medium clay loam.
74	14.3	40.6	18.4	93.9	.14	1.800	.08	.069	0.9	Clay loam irrigated land.
75	15.5	46.5	20.0	106	-4.5	2.100	2.1	-----	2.0	Ground water near surface.
76	20.7	37.1	22.0	112	2.6	2.630	1.00	.735	0.9	Uniform clay loam.
77	23.3	46.4	24.8	122	6.0	1.980	3.0	1.999	2.5	Gravelly sidehill.
78	23.5	53.3	25.4	127	12.1	3.140	3.9	2.482	3.1	Medium clay loam shale $\frac{1}{2}$ disintegrated.
79	45.0	73.9	47.0	133	1.90	2.930	.65	.226	0.5	Medium clay loam.
80	17.0	42.2	21.0	136	9.4	2.833	3.3	2.585	2.4	Sand and gravel.
81	38.0	99.5	40.0	140	11.3	4.960	2.3	.932	1.6	Shallow clay loam.
82	37.0	94.8	38.6	146	5.8	6.260	.92	.393	0.6	Do.
83	18.3	52.4	22.4	146	10.5	3.400	3.1	2.256	2.1	Heavy clay loam.
84	-----	-----	-----	175	1.31	13.000	.10	-----	0.1	Perrine coulee.
85	67.5	116	68.2	192	2.3	3.809	.60	.145	0.3	Clay loam and lava.

TABLE XXIV.—*Seepage losses from canals—Continued.*

No.	Average width of water surface.	Area water surface.	Wetted perimeter.	Discharge at upper end of section.	Total loss in section.	Length of section observed.	Loss per mile.	Loss per square foot wetted area per 24 hours.	Loss per mile.	Remarks.
	Feet.	Square feet.	Feet.	Second-feet.	Second-feet.	Miles.	Second-feet.	Cubic feet.	Per cent.	
86	68.1	125	68.8	207	8.4	4.185	2.0	0.480	1.0	Clay loam, hardpan, lava rock.
87	22.4	67.7	27.0	214	10.2	3.090	3.3	2.001	1.5	Gravel and clay loam.
88	21.3	97.5	27.5	242	1.33	3.530	.38	.224	0.2	Heavy gravel.
89	26.4	91.6	31.0	243	3.6	1.920	1.88	.988	0.8	Compact clay loam.
90	21.0	96.0	28.8	244	.13	3.500	.04	.021	0.01	Banks sandy.
91	21.9	101.4	30.8	260	10.0	2.450	4.1	2.048	1.6	Very sandy sidehill.
92	24.8	106	33.0	265	3.4	2.850	1.19	.502	0.4	Sandy loam.
93	25.8	107	31.3	270	-2.0	2.110	.95	-----	0.4	Cement gravel.
94	25.1	113	32.8	272	6.0	2.440	2.5	1.227	0.9	Sandy loam.
95	31.3	130	36.0	295	13.6	2.260	6.0	2.735	2.0	Porous gravels, evidently seepage.
96	68.0	159	70.5	308	8.4	3.870	2.2	.500	0.7	Clay loam and lava.
97	68.0	171	70.3	332	24.3	4.180	5.8	1.353	1.7	Clay loam, hardpan.
98	32.0	122	36.5	333	-.76	2.620	.29	-----	0.1	Impervious clay loam.
99	Ch'k.	Basin.	-----	344	34.2	-----	-----	-----	-----	Clay loam, hardpan.
100	38.3	142	42.4	420	12.5	5.840	2.1	.826	0.5	Gravel, sand, clay.
101	Ch'k.	Basin.	-----	476	28.2	-----	-----	-----	-----	Clay loam, hardpan.
102	53.5	265	57.0	760	-4.0	2.180	1.84	-----	0.2	Gain, gravel.
103	56.7	288	61.4	783	10.4	2.260	4.6	1.227	0.6	Compact gravel and clay.
104	53.0	290	58.9	788	-12.7	2.140	5.9	-----	0.8	Composite clay and clay irrigated land above canal.
105	57.0	316	62.6	832	11.1	2.060	5.4	1.408	0.6	Uniform clay loam.
106	60.0	319	64.8	877	20.9	2.940	7.1	1.701	0.8	Do.
107	-----	-----	-----	1,615	108	3.410	31.7	-----	2.0	Varying clay loam.
108	-----	-----	-----	1,755	126	5.110	24.7	-----	1.4	Bottom on creviced lava rock.
109	-----	-----	-----	1,870	108	8.410	12.8	-----	0.7	Coulee and ditch.
110	-----	-----	-----	1,890	19.2	2.750	7.0	-----	0.4	Gravel, sidehill.
111	-----	-----	-----	2,006	116	8.790	13.2	-----	0.7	Clay loam creviced lava rock.
112	-----	-----	-----	2,379	13.5	4.390	3.1	-----	0.1	½ concrete lined, ½ clay.
113	104.0	784	110.5	2,737	93.0	5.350	17.4	2.574	0.6	Deep uniform clay loam.
114	107.3	829	114.3	2,798	30.4	6.070	5.0	.719	0.2	Do.
115	107.5	831	114	2,857	27.0	2.650	10.2	1.462	0.4	Do.
116	-----	-----	-----	2,934	54.0	-----	-----	-----	-----	Reservoir.
117	118.0	955	123	3,097	148	5.050	29.3	3.899	0.9	Deep clay loam.
118	123.0	984	129	3,192	167	3.350	49.9	6.324	1.6	Clay loam, underlain by creviced lava rock.

Table XXV shows the range of the losses to which the canals were subject in per cent per mile and in cubic feet per square foot of wetted area per 24 hours.

TABLE XXV.—*Range of seepage losses from canals.*

	Per mile.	Loss per square foot per 24 hours.
Minimum loss.....	Per cent.	Cubic feet.
Maximum loss.....	1-5.5	(¹)
Average loss (109 sections).....	58.3	6.32
	7.4	1.21

¹ Gain.

The effect of capacity and other factors upon the losses is shown by the curves in figure 13, which are based upon all of the data secured after eliminating the few sections which showed a gain. These curves

indicate that losses per square foot of wetted area are largely independent of the volume of water flowing in the canal, but that they are slightly influenced by the depth of water over the wetted area, and that the per cent loss per mile is greatly influenced by capacity where

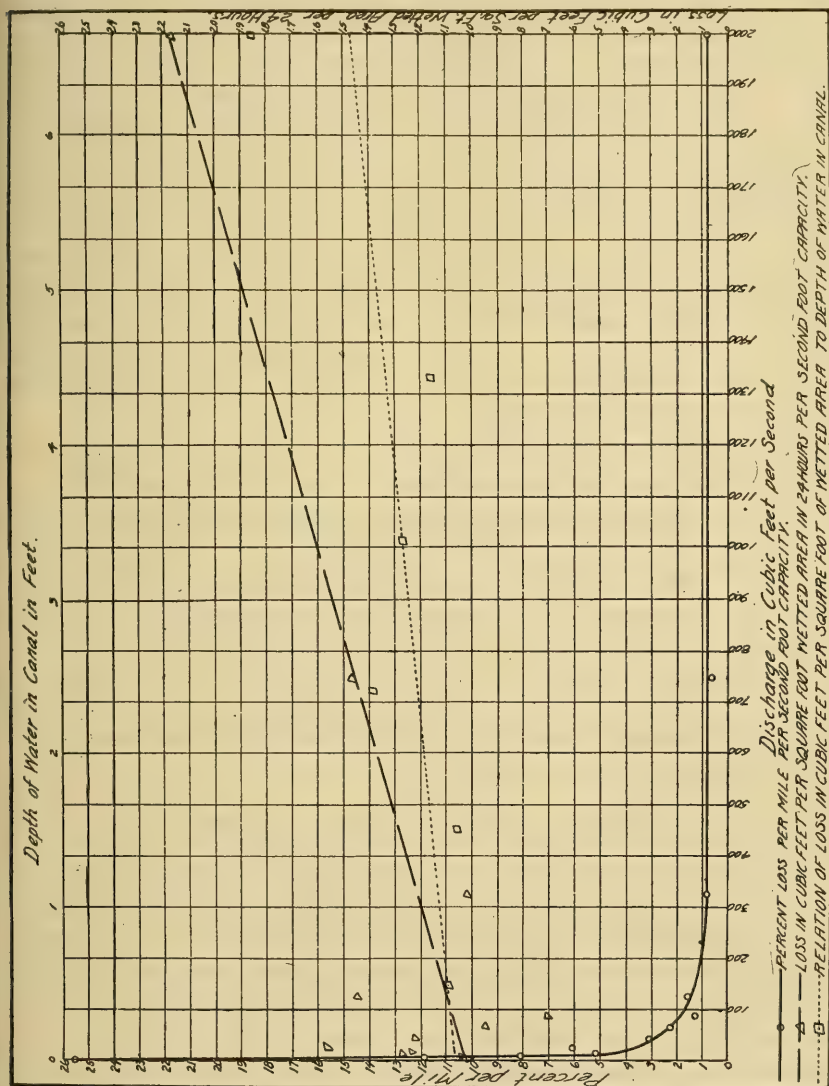


FIG. 13.—Effect of capacity of canal and depth of water on loss in per cent per mile and in cubic feet per square foot of wetted area.

quantities less than 200 second-feet are carried, but that with capacity in excess of 200 second-feet the percentage of loss is remarkably constant. Great care must be used in the designing of small canals to allow for a sufficiently large per cent of loss.

A study of the results shows, among other things:

(1) Small laterals carrying 1 second-foot and less almost invariably lose a large part of the water carried, and the percentage of loss decreases rapidly as the volume carried is increased, thus emphasizing the desirability of rotation systems where the necessity of carrying small amounts is eliminated.

(2) Since certain types of soil have a fairly uniform loss per square foot of canal bed, canals should be designed, other things being equal, with as small a wetted perimeter as possible in comparison to their cross sections.

(3) Porous irrigated land above a canal may cause it to gain instead of lose.

(4) Canals in average southern Idaho soil, which is a medium clay loam, should be designed to withstand a loss of 0.5 to 1.5 cubic feet per square foot of canal bed in 24 hours; 0.5 cubic foot per square foot per day is a safe basis for impervious clay loam soil, about 1 cubic foot per day for medium soil, and 1.5 to 2 cubic feet per square foot per day is a safe basis for somewhat pervious soils.

(5) One per cent per mile is a safe basis for the loss in medium southern Idaho soil with capacities in excess of 200 second-feet.

(6) Canals in gravelly soil should be designed to withstand a loss of 2.5 to 5 cubic feet per square foot of canal bed in 24 hours, depending upon the porosity of the gravel, although it is probable that lining would be profitable if the higher loss were experienced. The procedure must be determined by local economic conditions.

(7) A project having a comparatively long main canal, constructed through earth and unlined, may lose from 20 to as high as 50 per cent of the water diverted before it reaches the farms even in the impervious soils. (See fig. 13.)

SURVEY OF WASTE LAND IN IDAHO.

It has long been known that not every acre of the gross area contained in a project is irrigated. Engineers, for lack of more accurate data, have commonly assumed that 20 per cent of a typical project is unirrigated because of high spots, corrals, county and private roads, railroad rights of way, etc. Water has been increasing in value to such an extent that there is a great incentive to base projects upon narrower margins each year, and it was evident that the above factor should be carefully determined in order to allow of a design that would not only be economical but would safeguard the future of the newer projects. For the purpose of determining the extent of unirrigated land which exists in a high-class, intensively cultivated project in any one year from all causes, 16,067.8 acres of typical irrigated land, located in two contiguous bodies in the best part of two typical

irrigated districts, were surveyed. Twenty-six sections were surveyed, 20 of them being located under the old canals in the heart of the Boise Valley, in the vicinity of Meridian, and 6 sections in the heart of the South Side Twin Falls project near Kimberly. The entire survey was made with a transit and chain, each crop and each type of waste land being carefully noted. The field notes were plotted on detail paper on a scale of 200 feet to the inch, and the areas were determined with a polar planimeter. The areas surveyed were typical of the better class of Idaho irrigation practice in every respect, and the detailed results secured are shown in the following tables. For convenience the various irrigated areas are grouped in Table XXVI, and the nonirrigated or waste areas in Table XXVII. As numbered in the first column, the 26 sections are identical in the two tables. Nos. 1 to 6, inclusive, in both tables give the data for the six sections near Kimberly, and Nos. 7 to 26, inclusive, for the 20 sections near Meridian.

TABLE XXVI.—*Acres actually irrigated.*

No.	Hay.		Grain.		Pasture.		Potatoes.		Orchard.		Garden.	
	<i>Acres.</i>	<i>P. ct.</i>	<i>Acres.</i>	<i>P. ct.</i>	<i>Acres.</i>	<i>P. ct.</i>	<i>Acres.</i>	<i>P. ct.</i>	<i>Acres.</i>	<i>P. ct.</i>	<i>Acres.</i>	<i>P. ct.</i>
1.....	112.3	23.3	83.7	17.4	55.5	11.5	14.4	3.0	76.7	15.9	8.1	1.7
2.....	95.9	14.9	263.9	40.9	64.1	9.9	14.9	2.3	21.4	3.3	4.2	.7
3.....	228.4	35.5	67.4	10.5	71.9	11.2	12.9	2.0	25.8	4.0	11.3	1.8
4.....	86.6	15.8	112.6	20.6	9.1	1.7	19.7	3.6	204.6	37.5	.3	.1
5.....	67.5	14.0	57.7	12.0	12.8	2.6	41.3	8.5	78.7	16.3	2.2	.5
6.....	52.5	10.9	96.5	20.1	34.7	7.2	15.9	3.3	66.6	13.8	1.7	.3
7.....	292.6	45.4	134.0	20.8	55.5	8.6	0	0	111.7	17.3	.4	.1
8.....	202.3	31.3	212.4	32.8	100.1	15.5	0	0	12.6	1.9	8.5	1.3
9.....	223.5	34.6	184.0	28.5	134.5	20.8	0	0	56.5	8.7	0	0
10.....	72.3	11.2	88.7	13.7	42.6	6.6	0	8	379.0	58.6	1.1	.2
11.....	220.8	35.9	57.9	9.4	121.0	19.7	0	0	183.1	29.8	1.0	.2
12.....	186.9	29.3	109.4	17.1	177.7	27.8	0	0	104.7	16.4	3.0	.5
13.....	167.5	26.3	104.3	16.4	155.7	24.5	0	0	154.0	24.2	5.6	.9
14.....	151.6	25.0	148.3	24.4	111.1	18.3	0	0	129.3	21.3	9.9	1.6
15.....	134.6	20.5	171.7	26.1	217.2	33.1	0	0	67.1	10.2	10.3	1.6
16.....	139.5	21.8	200.0	31.3	113.9	17.8	18.2	2.8	105.6	16.5	7.9	1.2
17.....	215.9	33.4	308.7	47.8	10.9	1.7	0	0	33.3	5.2	2.7	.4
18.....	219.3	34.1	253.8	39.5	18.5	2.9	0	0	43.6	6.8	2.5	.4
19.....	319.3	49.4	205.7	31.8	82.9	12.8	0	0	6.3	1.0	0	0
20.....	151.3	23.8	309.1	48.6	100.1	15.7	0	0	17.0	2.7	5.8	.9
21.....	204.3	32.0	202.8	31.8	89.0	14.0	0	0	45.2	7.1	3.0	.5
22.....	191.3	30.2	208.1	32.9	89.7	14.2	0	0	109.3	17.3	.6	.1
23.....	84.7	13.3	72.0	11.4	305.9	48.2	0	0	121.6	19.2	4.4	.7
24.....	117.1	18.3	261.8	40.9	87.2	13.6	0	0	119.7	18.7	0	0
25.....	197.5	31.0	233.9	36.7	120.9	18.9	0	0	16.1	2.6	7.4	1.2
26.....	281.9	43.5	179.4	27.7	65.1	10.0	0	0	71.2	11.0	3.7	.6
Total.....	4,417.4	.....	4,327.8	.....	2,447.6	.....	137.3	.....	2,300.7	.....	105.6	.....
Percentage.	.....	27.5	.....	26.9	.....	15.2	.....	.9	.....	14.7	.....	.7

TABLE XXVI.—*Acres actually irrigated*—Continued.

No.	Clover.		Sagebrush, will be irrigated.		Corn, beans, and peas.		Vineyards and berries.		Miscella- neous.		Total.	
	Acres.	P. ct.	Acres.	P. ct.	Acres.	P. ct.	Acres.	P. ct.	Acres.	P. ct.	Acres.	P. ct.
1.....	21.3	4.4	0	0	9.1	1.9	0.9	0.2	58.1	12.5	440.1	91.4
2.....	0	0	7.4	1.1	.1	0	.6	.1	89.5	13.8	562.0	87.0
3.....	10	0	5.6	.9	0	0	0	0	155.8	24.2	579.1	90.0
4.....	6.5	1.9	10.1	1.9	10.5	1.8	1.3	.2	37.9	6.9	499.2	91.4
5.....	14.6	3.0	0	0	129.7	26.8	0	0	34.2	7.1	438.7	90.8
6.....	52.4	10.9	11.9	2.4	80.0	1.7	0	-----	18.2	3.8	430.4	89.2
7.....	0	0	0	0	0	0	.7	.1	0	0	594.9	92.3
8.....	0	0	58.4	9.0	0	0	0	0	0	0	594.3	91.9
9.....	0	0	0	0	0	0	0	0	1.7	.3	600.2	92.8
10.....	0	0	0	0	0	0	0	0	10.8	1.7	594.5	91.9
11.....	0	0	0	0	0	0	0	0	0	0	583.8	95.0
12.....	0	0	0	0	0	0	0	0	4.0	.6	585.7	91.6
13.....	0	0	3.5	.6	0	0	0	0	0	0	590.6	92.8
14.....	0	0	0	0	10.1	1.7	0	0	0	0	560.3	92.4
15.....	0	0	0	0	0	0	2.2	.3	0	0	603.1	91.8
16.....	0	0	0	0	0	0	0	0	0	0	585.1	91.5
17.....	0	0	3.8	.6	0	0	0	0	0	0	575.3	89.2
18.....	0	0	40.1	6.2	0	0	0	0	0	0	577.8	89.8
19.....	0	0	0	0	0	0	0	0	0	0	614.2	95.0
20.....	0	0	0	0	1.6	.3	0	0	6.2	1.0	591.1	93.0
21.....	0	0	58.9	9.2	0	0	0	0	0	0	603.2	94.6
22.....	0	0	0	0	0	0	0	0	0	0	599.0	94.6
23.....	0	0	0	0	0	0	0	0	0	0	588.6	92.7
24.....	0	0	0	0	0	0	0	0	7.2	1.1	593.0	92.5
25.....	0	0	0	0	0	0	0	0	1.5	.3	577.3	90.6
26.....	0	0	0	0	0	0	0	0	9.0	1.4	610.3	94.1
Total.....	94.8		199.7		241.1		5.7		434.1		14,771.8	
Percentage.....		.6		1.2								91.9

¹ Flax.TABLE XXVII.—*Waste or nonirrigated acreage.*

No.	Corrals.		Barn and stack yards.		Fence rows.		Canals and ditches.		County and private roads.	
	Acres.	P. ct.	Acres.	P. ct.	Acres.	P. ct.	Acres.	P. ct.	Acres.	P. ct.
1.....	4.9	1.01	0	0	7.7	1.6	3.4	0.7	10.4	2.2
2.....	6.5	1.0	0.7	0.1	9.0	1.4	3.9	.6	14.2	2.2
3.....	5.8	.9	.1	0	7.8	1.2	9.3	1.5	13.2	2.0
4.....	2.6	.4	1.0	.2	6.5	1.2	7.5	1.4	16.4	3.0
5.....	5.7	1.2	0	0	12.5	2.6	2.7	.6	14.1	2.9
6.....	6.6	1.4	0	0	9.8	2.0	6.2	1.3	14.7	3.1
7.....	6.7	1.0	.9	.2	2.0	.3	10.0	1.6	12.3	1.9
8.....	5.3	.8	.8	.1	1.5	.2	14.2	2.2	12.3	1.9
9.....	3.4	.5	3.3	.5	1.0	.2	14.4	2.2	13.0	2.0
10.....	3.0	.5	.7	.1	2.8	.4	9.2	1.4	14.0	2.2
11.....	1.4	.2	2.7	.4	1.2	.2	5.4	.9	13.4	2.2
12.....	8.4	1.3	2.2	.3	1.9	.3	9.3	1.5	14.9	2.3
13.....	.8	.1	1.5	.2	1.7	.3	5.9	.9	13.3	2.1
14.....	0	0	.3	.0	1.4	.2	4.8	.8	13.5	2.2
15.....	4.2	.6	.6	.1	2.0	.3	4.7	.7	14.9	2.3
16.....	4.0	.6	0	0	1.8	.3	10.8	1.9	11.7	1.8
17.....	6.7	1.0	0	0	1.8	.3	9.5	1.5	13.3	2.1
18.....	1.6	.3	.5	.1	1.5	.2	14.8	2.3	15.2	2.4
19.....	2.6	.4	1.9	.3	1.2	.2	9.1	1.4	12.4	1.9
20.....	7.9	1.2	1.6	.3	2.3	.4	11.4	1.8	12.3	1.9
21.....	.2	0	3.0	.5	1.0	.2	9.3	1.5	12.7	2.0
22.....	.4	.1	.4	.1	1.1	.2	13.0	2.1	12.1	1.9
23.....	.4	.1	0	0	2.4	.4	13.5	2.1	15.0	2.4
24.....	1.7	.3	.4	.1	.7	.3	8.1	1.3	12.5	2.0
25.....	5.2	.8	1.6	.3	1.7	.3	11.9	1.9	15.5	2.4
26.....	4.4	.7	.6	.1	2.6	.4	7.2	1.1	14.2	2.2
Total.....	100.0		24.8		87.9		229.5		351.5	
Percentage.....		.6		.2		.6		1.4		2.2

TABLE XXVII.—*Waste or nonirrigated acreage*—Continued.

No.	Railroad right of way.		Building sites.		Coulees, sloughs, and creeks.		Miscellaneous.		Total.		Total acreage in section considered.
	<i>Acres.</i>	<i>P. ct.</i>	<i>Acres.</i>	<i>P. ct.</i>	<i>Acres.</i>	<i>P. ct.</i>	<i>Acres.</i>	<i>P. ct.</i>	<i>Acres.</i>	<i>P. ct.</i>	
1.....	5.7	1.1	0	0	9.7	2.0	0.4	0.1	42.2	8.7	482.3
2.....	12.0	1.9	0	0	31.8	4.9	5.4	.8	83.6	12.9	645.6
3.....	0	0	0	0	25.4	3.9	2.9	.5	64.5	10.0	643.6
4.....	.6	.1	0	0	12.3	2.3	.1	0	47.0	8.6	546.2
5.....	0	0	0	0	6.8	1.4	2.6	.5	44.4	9.2	483.1
6.....	5.8	1.2	0	0	7.1	1.5	2.1	.4	52.3	10.9	482.7
7.....	0	0	6.7	1.0	10.3	1.6	1.0	.2	49.9	7.8	644.8
8.....	0	0	7.8	1.2	8.7	1.4	2.7	.4	53.3	8.2	647.6
9.....	0	0	8.5	1.3	1.4	.2	1.4	.2	46.4	7.2	646.6
10.....	0	0	8.8	1.4	14.1	2.2	0	0	52.6	8.1	647.1
11.....	0	0	6.3	1.0	.2	0	.2	0	30.8	5.0	614.6
12.....	3.7	.6	7.0	1.1	6.1	1.0	0	0	53.5	8.3	639.2
13.....	3.7	.6	12.0	1.9	7.2	1.1	0	0	46.1	7.3	636.7
14.....	3.9	.7	7.6	1.2	15.4	2.5	0	0	46.9	7.7	607.2
15.....	6.1	.9	9.4	1.4	12.0	1.8	0	0	53.9	8.2	657.1
16.....	3.6	.6	7.2	1.1	12.0	1.9	3.1	.1	54.2	8.5	639.3
17.....	24.1	3.7	3.2	.5	10.2	1.6	1.7	.3	70.5	10.9	645.5
18.....	24.2	3.8	4.5	.7	3.0	4.7	.0	0	65.3	10.2	643.1
19.....	0	0	5.0	.8	0	0	.5	.1	32.7	5.1	646.9
20.....	0	0	7.2	1.1	1.5	.2	.4	.1	44.6	7.0	635.7
21.....	0	0	2.5	.4	0	0	5.8	.9	34.5	5.4	637.7
22.....	0	0	6.5	1.0	0	0	1.1	.2	34.2	5.4	633.2
23.....	0	0	7.1	1.1	7.7	1.2	0	0	46.1	7.3	634.7
24.....	0	0	8.0	1.3	15.1	2.4	.5	.1	48.0	7.5	641.0
25.....	0	0	7.4	1.2	14.7	2.3	2.4	.4	60.4	9.5	637.7
26.....	0	0	6.6	1.0	2.1	.3	.4	.1	38.1	5.9	648.4
Total.....	93.4	.....	139.3	.....	234.8	.....	34.7	.....	1,296.0	.....	16,067.8
Percentage.....		.6		.9		1.6		.2		8.1	

A small part of the land surveyed, as indicated by the tables, was yet uncleared and uncultivated and is classed as sagebrush. The survey having been made during two winter seasons, no determination as to the extent of the fallow land could be made. The proportion of this land, however, was practically negligible and could not possibly have exceeded 1 or 2 per cent. The 20 sections included in the investigation in the vicinity of Meridian averaged 10.65 farms per section. Space will not permit of a detailed description of each section included in the investigation or of the results obtained. The results show, in addition to other factors, that the total land unirrigated from all possible causes, even including the unirrigated strips along the fence rows, amounted to only 8.1 per cent of the total area surveyed. The land included was not the best nor the most intensively cultivated of Idaho irrigated land, but it undoubtedly did represent a little better than average conditions, for neither the main canal nor the rough, rolling land that is common along the main stream was included. The data secured therefore seem to demonstrate that well-developed projects will never contain more than 10 to 12½ per cent of land which is waste or unirrigated in any one year from all different causes, provided the percentage is based upon no greater gross area than that from which annual maintenance can be reasonably expected.

PROPER DUTY OF WATER FOR IDAHO.

The investigations have determined the factors which must be taken into consideration in determining the proper duty for an entire irrigation project. The first factor is the proper duty of water at the land. The results of the investigation indicate that under conditions similar to those obtaining in Idaho on a normal project with medium clay loam should furnish sufficient water so that 2 acre-feet can be retained upon each and every irrigated acre during the season; that this quantity should be delivered under a rotation system in heads of such sizes that economical use can be secured; and that where a project is devoted one half to grain and the other half to alfalfa or other crops requiring a similar volume of water, 18.7 per cent of this 2 acre-feet should be delivered during May, 28.3 per cent during June, 32.8 per cent during July, 17.2 per cent during August, and 2 per cent during the first half of September, there being but little need for irrigation during the month of April and practically none after the middle of September, provided stock water or that used for domestic purposes is not taken into consideration. It has been shown that the farmer must receive approximately $2\frac{1}{4}$ feet of water per acre at the farm in order for him to retain 2 feet per acre upon the land. Where projects consist in whole or in part of porous soils or of soils with porous subsoils lying closer to the surface than 6 feet, more than $2\frac{1}{4}$ feet per acre should be delivered to the consumers, the quantity required being largely dependent upon the porosity of the soil.

A conservative estimate of the transmission losses should be made in advance for each project, in either cubic feet per square foot of wetted area or per cent per mile, from the quantity required of canals to furnish sufficient water to all parts of a project. A normal project will be found to lose from 20 to 40 per cent of all water diverted before the water can be delivered to the farmer.

After the duty of water at the land, the size of the project, and the probable transmission losses have been determined, the net area which may be irrigated may be readily found. It then becomes necessary to calculate the extent of waste or nonirrigated land from all causes which will finally be contained in the project. This, added to the net area which can be irrigated, will give the gross area of the project. The extensive survey that was made for the determination of this factor seems to indicate that 90 per cent of a normal project will be irrigated every year after the project is fully developed.

The investigation has demonstrated the adequacy of 2 feet per acre for diversified crops on the better class of soils, but it requires careful husbandry to render this quantity adequate, and it seems evident that but few projects will ever exist, with conditions similar

to those in south Idaho, where an allotment of less than this supply will be justified. It is believed, however, that the volume of water which will produce the maximum yield of crop on any certain variety of soil is in but few cases the proper and economic duty. It is very evident that the cost of the land, of water, the value of the crops produced, and the cost of producing them, as well as the volume of water which will produce the largest yield, must all be taken into consideration when determining the duty for any project. In many places the largest crop has been produced where the most water has been applied, but the yield has been in but few cases proportional to the quantity of water used, and in view of this there is no doubt that, broadly speaking, one would be justified in opening up a project with a higher duty of water where water is very valuable and land comparatively cheap than where land is high and water comparatively inexpensive. The determination of the proper supply of water for an irrigation project is a very serious problem and one that must be given the most careful consideration, for it is fully as serious to err on the side of too little water as it is on the side of too much. If too little water is allotted, the farmers never can produce profitable crops and the lands never will reach their highest possible value, while if too much is allotted the ultimate irrigated area is not only cut down, but the excess supply is almost invariably used, resulting in the rapid water-logging and deterioration of the irrigated lands.

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EXPERIMENTS IN VACCINATION AGAINST
ANTHRAX.¹

By ADOLPH EICHHORN, *Chief of the Pathological Division.*

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PREVALENCE OF ANTHRAX AND METHODS OF CONTROL.

Anthrax is a disease that is widely spread throughout the world, and in the United States it is being recognized as one of the most destructive scourges of live stock. In certain sections it is more prevalent than in others, particularly in the Southern States, and since no determined effort has been made toward its suppression it appears to be on the increase, its presence now being recorded in localities where it has never before been recognized.

As the spores of the causative agent of anthrax retain their virulence and remain lodged in the soil in an active state for many years in the infected localities, it is very difficult to prevent the spread of the infection, and the eradication of the disease is thereby rendered a most serious problem.

Various factors have to be considered in the prophylactic control of anthrax, such as the prevention of the continued impregnation of

¹ The author was ably assisted in the technical part of this work by Dr. Raymond A. Kelser, assistant in pathology and bacteriology, to whom credit is due for the painstaking and careful execution of the details of the experiments.

NOTE.—This bulletin is of interest to stock raisers and veterinarians generally.

the soil with the virus by the proper disposition of the carcasses of animals that have died of the disease, the destruction of the virus contained in the soil by its proper drainage and cultivation, and the prevention of outbreaks through the immunization of the susceptible animals.

In order to attain the greatest success in the control and eradication of the disease, it would appear that the best results can be accomplished only through proper attention to all of the above factors. The execution of these measures would require the earnest cooperation of the stock owners, but even then, on account of the peculiar geographical conditions of certain parts of the country, the drainage and cultivation of the land would not always be feasible, and our efforts must therefore be directed principally toward the sanitary measures and protective vaccination. The enforcement of proper sanitary police regulations in connection with the control of anthrax would no doubt effect a material reduction of the disease, but unfortunately it is rather a difficult task to obtain the cooperation of the interested parties.

The proper disposition of the infective material, particularly the carcasses, should be considered of the utmost importance, since such material constitutes the greatest source of danger toward the spreading of the disease. Drainage from the soil polluted by infected carcasses may carry the infection to distant points and deposit the spores over large areas hitherto uninfected. Buzzards and other birds (Dalrymple), dogs, and even flies may also carry the infection from such sources into uninfected localities. Therefore, in an effort to control the disease, an educational propaganda must be carried out and stringent compulsory measures adopted for the proper disposition of the infective material from premises where the disease appears among the stock.

PROTECTIVE VACCINATION.

A material reduction and a checking of the disease may be successfully accomplished by periodical vaccination of all stock in infected localities. This method, even if practiced alone, would have splendid results in minimizing the losses from the disease in anthrax localities. However, such vaccination must be carried out regularly and irrespective of whether the disease has already appeared on the premises.

Fortunately we have at our command various methods of vaccination which have proved highly efficient in the production of immunity from anthrax. As a matter of fact, this was one of the first infectious diseases in which protective vaccination was successfully demonstrated, and we are indebted to Pasteur for devising the pro-

cedure of the vaccination for this purpose. Pasteur proved that anthrax bacilli when cultivated at a temperature of from 42° to 43° C. will gradually lose their virulence, and also that when removed from such an attenuating temperature and cultivated under normal incubation temperature they will not change their pathogenicity. Thus cultures attenuated for 24 days will be pathogenic for mice but not for guinea pigs and rabbits, whereas if attenuated for only 12 days at the higher temperature they will be virulent for mice and guinea pigs but not for large rabbits. The attenuated cultures will retain their reduced virulence under ordinary conditions, and only in very exceptional instances has any increase of virulence been observed. This characteristic of the anthrax bacillus led Pasteur to employ the attenuated forms of the anthrax cultures for vaccination purposes. Accordingly he prepared a weakened vaccine from cultures which had been attenuated for 24 days (*premier vaccin*), and for a second injection cultures which had been attenuated for 12 days (*deuxième vaccin*). In the epoch-making demonstration at Pouilly le Fort, before a commission appointed by the French Government, he successfully demonstrated its effectiveness on sheep and cattle. In this instance the vaccinated animals withstood the injection of virulent anthrax bacilli, whereas the controls died. Since that time vaccination against anthrax by the Pasteur method has been very extensively employed throughout the world. Many millions of animals have been vaccinated by this method, and the results in general must be considered very favorable.

At the same time it must be acknowledged that in vaccination by the Pasteur method it is essential to have a potent vaccine and one which is properly tested for its pathogenicity. There are disadvantages in this method of vaccination and these must be given due consideration. The unstable keeping quality of the Pasteur vaccine is a very important factor to be considered. Experience in this line has proved that Pasteur vaccine may deteriorate within a very short time after its preparation, and this has also been demonstrated during the work of the Bureau of Animal Industry in the control of the manufacture of biological products, when periodical tests were undertaken with those of various manufacturers. In repeated instances a vaccine proved inert within three months of its preparation. At other times it remained potent for a period of a year. This no doubt is due to the method of preserving and handling the product. When exposed to light and warm temperature it deteriorates very rapidly, and when it is considered that the products of manufacturers may be stored under unfavorable conditions in branch houses and on the shelves in rural drug stores the loss of potency can be readily explained. For this reason it seems wise to reduce the time limit for

the use of Pasteur anthrax vaccine to three months from the date of its preparation.

The injection of an inert product into animals would impart to the stock owners and veterinarians who employ it a false sense of security and would bring this method of vaccination into disrepute. At times no doubt great losses have resulted from the application of inert vaccines.

Other disadvantages of the Pasteur method which must be considered are, first, that it requires two handlings of the animals before immunity is established; second, that the losses from vaccinations are not insignificant; third, that its standardization is not carried out very accurately; and, fourth, that its administration in herds where the disease has already made its appearance is liable to induce the disease, through the reduction of the resistance of the animal during the process of vaccination, and for this last reason it is best adapted for use only with herds in which the disease has not yet appeared.

These deficiencies of the method have been recognized by many investigators, who have endeavored to devise other methods of vaccination, and particular attention has been directed toward the preparation of a spore vaccine, because of its superior keeping qualities. In Russia at the present time the method of Zenkowsky, and in Hungary a spore vaccine prepared by Detre, are being successfully employed; although, aside from their keeping qualities, these products have all the other disadvantages of the Pasteur method. Successful vaccination by spore vaccines was also demonstrated by Nitta, in Japan, and by others. Other means of vaccination with attenuated living cultures, aggressions, dead bacteria, etc., were tried, but proved of no advantage.

Sclavo, Sobernheim, and others have established that injections of increasing amounts of virulent cultures into immune animals produced a serum which has great protective value against anthrax. Such protective serum may be produced in the various susceptible animals.

PRODUCTION OF SERUM.

The animals which are selected for the preparation of serum are subjected to a preliminary treatment either by sero-vaccination or by Pasteur's method, then at certain regular intervals they are infected with increasing doses of virulent anthrax cultures. For this purpose they receive in about 10 to 14 days following the preliminary treatment an injection of from 0.005 to 0.001 of a loopful of virulent culture. In sheep it is advisable to exercise greater care, especially at

the first injection of virulent material, when a very small quantity of culture should be employed, whereas in cattle and horses it is not necessary to employ less than 0.005 of a loopful. The first injection of virulent culture is usually followed by a considerable reaction, inasmuch as the animals usually develop a febrile condition which persists for several days. The subsequent inoculations are then carried out at intervals of from 2 to 3 weeks in such a way that the dose is soon increased to a loopful, then to several loopfuls, and gradually to several agar cultures, and, finally, to an injection consisting of several large mass cultures. This is quite easily accomplished in cattle and horses, and in 3 to 4 months the animals may become so tolerant to this injection that they will withstand the subcutaneous inoculations of two to three mass cultures without noteworthy reaction. At times considerable extensive local infiltration may follow the injection, which, however, retrogresses within a short time and the general condition of the animals is only slightly influenced. In sheep the immunization causes greater difficulties on account of a greater susceptibility of these animals, and it is difficult to prevent a very small percentage of the animals which are being used for serum production from dying in the course of the hyperimmunization. Nevertheless it is possible, even in sheep, to produce such an immunity that they will withstand the injection of several mass cultures without reacting.¹

The more virulent the strain of the anthrax culture which has been used for the treatment of the animals the more care must be exercised in the course of the hyperimmunization, but in that case the anthrax serum would also be more potent. Therefore, it is advisable to use anthrax strains which have been recently obtained from fatal infections. It is also advisable to use strains of different origin for the immunization. It is immaterial whether bouillon cultures are used or suspensions from agar cultures, but it is more practical to use the latter method for the inoculating material, since in this instance the quantity of fluid to be injected may be limited to a relatively small amount. Quantities of 500 to 1,000 c. c. of the bouillon cultures cause, as can be readily seen, considerable technical difficulty for injection, whereas the suspensions from four or five mass cultures may be readily distributed in 50 to 60 c. c. of fluid. Fresh cultures which have been cultivated for about 24 hours at 37° C. are as a rule more suitable for inoculation, whereas older cultures with pronounced spore formations possess no advantages over the young cultures.

¹ Bureau of Animal Industry Bulletin 137, "Anthrax, with special reference to the production of immunity," by Charles F. Dawson. 1911. See p. 43.

The inoculations should be made subcutaneously. Intravenous injections as first employed by Sclavo are less effective. The potency of the anthrax serum is in no way increased by this method of immunization. Besides there exists the danger of emboli when in the later stages of the immunization process larger amounts of culture material have to be administered. Animals which have been treated with 'subcutaneous injections will produce finally an anthrax serum of remarkably high potency.

As a rule the animals which have received one to two agar cultures show a specific protective action of their serum, but for practical purposes it is not advisable to use such a serum. Generally only when the animals stand one-half to one mass culture is the potency of the serum sufficiently strong. A similar condition is manifested in animals used for the production of immune serums for other diseases, the individuals showing a varying response to the injection for the production of immune bodies, i. e., an animal will at times produce a potent serum relatively early, whereas another with the same method of treatment will develop a serum of the same potency only after a considerably longer preparatory treatment. Accordingly, from observation it has been noted that sheep produce the most potent serum, and in this species of animals the individual differences are of almost no consequence, so that almost every animal produces a good anthrax serum. Horses also produce a potent serum, although single individuals may show great variations. The anthrax serum from cattle is quite potent, but in its protective value it does not equal horse and sheep serum.

It is best to draw the blood 14 to 16 days after the last injection; an earlier bleeding should be avoided. Not infrequently it occurs that animals after an apparent recovery following the inoculation reaction and after a period in which they are free of fever on the eighth or ninth day suddenly develop a rise in temperature. This has been established by Sclavo and Burow. Then, again, repeated regular blood examinations showed that at this time and even later, up to the tenth and eleventh days following inoculation, occasional anthrax bacilli may appear in the blood of the animals in greater numbers.

The bleeding is carried out in the ordinary way, and the blood is collected in large sterilized glass cylinders or similar receptacles of about 2 or 3 liters capacity. Seven or eight liters of blood may be drawn from cattle, about the same quantity from horses, and about 1 to 1½ liters from sheep. After 2 or 3 days another bleeding is made. In this instance, however, only a small quantity of blood should be drawn. The animals resist these operations very readily, and after a lapse of 14 days they are ready for another injection,

which is then followed in from 14 to 16 days by repeated bleedings. Thus, in the period of a year, the same animals may be bled 10 to 11 times, and such animals can be used in this way for several years, alternating the injections with the bleedings, provided they are kept in a well-nourished and healthy condition.

In order to obtain the largest possible yield of serum from the blood drawn into the glass cylinders a weight is attached to the same and released onto the clotted blood in about 12 hours after being drawn. The diameter of the weight is about half an inch less than the cylinder and its weight is about 2 pounds. In about 24 hours the clear serum is then siphoned into sterile bottles and preserved with 0.5 per cent of carbolic acid. If proper precautions have been practised, it is not necessary to pass the serum through Berkefeld filters; however, if there is the slightest doubt as to its sterility, it is desirable to filter the serum before bottling. It is advisable to distribute the serum in various-sized brown bottles, which should be securely corked and paraffined.

STANDARDIZATION OF THE SERUM.

The testing of the serum must be carried out primarily to determine its potency. It is to be regretted that for this purpose there are no accurate or definite methods known, and it is almost impossible to establish the absolute protective value of the serum, because the animals on which it is being tested are so very highly susceptible to the disease. Nevertheless, it is possible to establish a relative value for all practical purposes through laboratory experiments, and some investigators believe that rabbits are best adapted for the purpose. The standardization test as recommended by Sobernheim is still employed by various investigators. This test is carried out as follows:

Potency test for anthrax serum (Sobernheim).

Rabbit.	First injection.	Second injection.
A.....	2 c. c. of immune serum (intravenous).....	Follow immediately by a subcutaneous injection of 0.001 loopful of a suspension of virulent anthrax bacilli in 1 c. c. of 0.7 per cent sodium-chlorid solution.
B.....	3 c. c. of immune serum (intravenous).....	
C.....	4 c. c. of immune serum (intravenous).....	
D.....	5 c. c. of immune serum (intravenous).....	
E.....	6 c. c. of immune serum (intravenous).....	
F (control).....	0.001 loopful of a suspension of virulent anthrax bacilli in 1 c. c. of 0.7 per cent sodium-chlorid solution.	
G (control).....	do.....	

According to extensive experience, a serum is considered potent and satisfactory for immunization purposes when at least two of the five rabbits given the serum remain alive and the others die later than the control animals. Should more than the two animals remain alive, while the control animals die in about 48 hours, the

serum has an extraordinary potency. It should be noted that it does not follow that those rabbits which receive the smallest serum doses should die, since not infrequently they may remain alive when the rabbits receiving larger doses succumb.

This method of standardization has not been proved as accurate and reliable as the test recommended by Ascoli, and which has been employed in the experimental work with serum prepared in connection with our experiments. In this test a 24-hour-old attenuated bouillon culture is used, which is of such virulence that when introduced subcutaneously in a 0.25 c. c. dose into 350-gram guinea pigs it will kill them in from two to three days. These test cultures must be previously standardized in such a way that they will kill guinea pigs which 24 hours previously have been injected intraperitoneally with 2 c. c. of normal serum. Guinea pigs treated in the same manner and with the same dose of titrated standardized immune blood serum must remain alive.

The testing of the serum is carried out on six guinea pigs, each receiving intraperitoneally 2 c. c. of the serum to be tested, and 24 hours later the established dose of the test culture is injected subcutaneously in the axillary region. The serum is considered satisfactory for immunization purposes if at least four of the guinea pigs remain alive over six days while the control animals die within three or four days. For protective and curative purposes in man, only such serum should be selected which, by carrying out the same conditions of the test, protect the guinea pig in 0.5 to 1 c. c. doses.

EXPERIMENTAL DATA.

HYPERIMMUNIZATION OF HORSES.

On September 8, 1914, two horses, Nos. 48 and 96, were vaccinated against anthrax according to Pasteur's method. On September 29 these two horses were given approximately 0.01 of a loopful of virulent anthrax bacilli subcutaneously. Horse No. 48 showed no apparent reaction following the injection. Horse No. 96, however, developed local anthrax at the point of inoculation. The swelling became enlarged and there was a considerable area of edema below the same. This condition persisted for approximately a week, and finally disappeared. The animal, however, showed no appreciable rise in temperature during this period.

The following table gives in detail the process of hyperimmunization:

Hyperimmunization of horses Nos. 48 and 96.

Date.	Amount of virus given each horse.	Result.
1914.		
Sept. 29.....	0.01 loopful.....	No apparent reaction in horse 48. Horse 96 developed anthrax at point of inoculation; large swelling; edema of neighboring tissue. Persisted about one week.
Oct. 24.....	1 loopful.....	No noticeable reaction in either animal.
Nov. 15.....	10 loopfuls.....	Do.
Dec. 9.....	5 c. c. of an emulsion, representing one-half growth of agar culture.	Horse 48 showed a temperature of 102.2° the following day; horse 96, 101°. Both animals developed a small, hard nodule at point of inoculation.
Dec. 29.....	20 c. c. of emulsion, representing washing of growth from 2 agar cultures.	Both animals developed small abscess at point of inoculation.
Jan. 19.....	30 c. c. of emulsion, growth from 8 agar cultures.	No reaction.
Feb. 6.....	40 c. c. of emulsion, growth from 2 mass cultures from flasks, surface area 6 by 2½ inches.	Slight reaction in horse 96. Horse 48 showed quite an intensive reaction, developing a large swelling at point of inoculation; persisted several days.
Mar. 5.....	50 c. c. of emulsion, growth from 4 mass cultures from flasks, surface area 6 by 2½ inches.	No apparent reaction.
Mar. 31.....	50 c. c. of emulsion, growth from 8 mass cultures from flasks, surface area 6 by 2½ inches.	Slight local reaction in each case.
Apr. 19.....	do.....	Do.
Apr. 28.....	do.....	Slight rise in temperature in both cases.
May 11.....	do.....	Slight temperature and local reaction.
May 24.....	do.....	Do.
June 12.....	do.....	Slight local reaction.

In the above work four strains of anthrax bacilli were used, known to us as "Davis," "6071," "Burt," and "Boener"—the first two strains being highly virulent types and the latter two very much weaker. In all cases where the larger amounts of the virus were given the injections were made at 4 to 6 different points in order to minimize abscess formation.

It might be well also to state here that the irregularity in the time between injections was due to the fact that this work was interfered with by the outbreak of foot-and-mouth disease in this country, and for this reason it was also impossible to subject the blood to periodical tests to ascertain its immunizing value at the different intervals between injections. Experience proved that horses may produce highly potent serum following the injection of the first or second mass cultures. It is therefore advisable to subject the blood of the animals to periodical tests for potency throughout the course of immunization.

On June 25, 1915, 6 liters of blood were drawn from each horse into the glass bleeding cylinders previously described. Since this date these animals have been bled regularly, 6 liters being taken from each horse, and an injection of virus made in the intervals between bleedings.

SERUM TESTS.

In standardizing our serum, that taken from each horse was tested separately. The following procedure was carried out: Three series

of guinea pigs were inoculated intraperitoneally with varying amounts of serum, and 48 hours later were injected with 0.25 c. c. of a 24-hour bouillon subculture of an attenuated strain known as "Davis D." This culture had been attenuated by growing it at a temperature of 42°-43° C. for a period of 20 days. Previous tests of this culture showed that it was uniformly pathogenic for guinea pigs, killing them in two to three days, but it failed to kill rabbits. The results of this test are contained in the following table:

Standardization tests of anthrax serum (serum injected intraperitoneally; virus 24 hours later subcutaneously).

SERUM 48.

Guinea pig No.	Amount of serum.	Amount of virus.	Result.
1.....	1.0 c. c.	0.25 c. c.	Remained alive.
2.....	1.5 c. c.	0.25 c. c.	Died on third day.
3.....	2.0 c. c.	0.25 c. c.	Remained alive.
4.....	2.5 c. c.	0.25 c. c.	Do.
5.....	3.0 c. c.	0.25 c. c.	Do.
6.....	3.5 c. c.	0.25 c. c.	Do.

SERUM 96.

1.....	1.0 c. c.	0.25 c. c.	Remained alive.
2.....	1.5 c. c.	0.25 c. c.	Do.
3.....	2.0 c. c.	0.25 c. c.	Died on third day.
4.....	2.5 c. c.	0.25 c. c.	Remained alive.
5.....	3.0 c. c.	0.25 c. c.	Do.
6.....	3.5 c. c.	0.25 c. c.	Do.

NORMAL HORSE SERUM.

1.....	1.0 c. c.	0.25 c. c.	Died on fourth day.
2.....	1.5 c. c.	0.25 c. c.	Died on third day.
3.....	2.0 c. c.	0.25 c. c.	Died on fourth day.
4.....	2.5 c. c.	0.25 c. c.	Remained alive.
5.....	3.0 c. c.	0.25 c. c.	Died on fourth day.
6.....	3.5 c. c.	0.25 c. c.	Died on third day.

In view of these results it was decided to use the "Davis D" culture in the preparation of our spore vaccine, to be used simultaneously with the serum.

Extensive tests to determine whether or not the immune serums possessed a bactericidal property proved negative.

PREPARATION OF SPORE VACCINE.

The four cultures used for the hyperimmunization of the horses were attenuated at a temperature of 42.5° C. for varying periods. From time to time they were tested for their pathogenicity by inoculation into mice, guinea pigs, and rabbits. The cultures, which were removed from the incubator after 20 days of attenuation, proved satisfactory for the purpose, inasmuch as the test inoculation demon-

strated their virulence for the mice and guinea pigs, but not for rabbits.

For the purpose of producing a spore vaccine it is desirable to use a peptone-free agar media and after inoculation with the attenuated culture to grow the organism at a temperature of 37.5° C. for 4 to 7 days, by which time an abundance of spores will have formed. The growth is then washed from the slants and collected in a sterile flask and heated at a temperature of 60° C. for one-half hour, to destroy the vegetative forms of the organism. A measured quantity of this suspension can then be plated out in the usual manner and the spore content of 1 c. c. of the suspension established. A dilution can then be made to the desired amount for inoculation purposes. Thus, if it is desired to use for vaccination 1,000,000 spores, it is best to dilute the vaccine to a quantity of which 1 c. c. would contain this number. Of such vaccine 1 c. c. would constitute the dose for cattle and horses, with correspondingly smaller doses for calves and sheep.

In all forms of vaccination against anthrax in sheep the greatest care must be exercised, since these animals are very susceptible to the disease, and at times vaccines which have no ill effects on cattle will prove fatal to sheep; therefore the dose of the spore vaccine for sheep should not be more than one-fourth the amount given cattle.

In the preparation of spore vaccines it is essential to submit every lot to a test for pathogenicity by inoculating approximately 250,000 spores—that is, 0.25 c. c. of the standard suspension—into guinea pigs and rabbits before employing the same for vaccination purposes. The guinea pigs should die in from 2 to 5 days, whereas the rabbits should remain alive.

In consideration of the keeping qualities of the spore vaccine, large lots can be prepared without fear of deterioration. In the bottling and storing of the same, however, proper care should be taken to prevent contamination.

TECHNIC OF ADMINISTRATION.

For immunization purposes by the simultaneous method the serum should be injected first. It is desirable to divide the herd into groups of 10 or 12 and inject first each animal of the group with the serum, following this with the injection of the spore vaccine. The serum should be injected on one side, either on the neck or back of the shoulder, and the spore vaccine on the other side, the injections being made subcutaneously.

In herds where the disease has already made its appearance it is necessary to take the temperatures of all the animals and to subject to the simultaneous vaccination only those that show no rise in tem-

perature. All others should be given the serum-alone treatment in doses varying in accordance with the severity of the symptoms manifested by the individual animals. If the examination reveals a considerable number of infections, it is advisable to use the serum alone for all the animals, and in 3 or 4 weeks to revaccinate by the simultaneous method.

The dosage should depend on the potency of the serum, serum of a high potency naturally being most desirable; thus, in some instances serum in 5 c. c. doses for large animals and 3 c. c. for smaller ones was found to be effective for immunization purposes. Unfortunately all hyperimmune animals do not yield serum of such high potency, and for this reason it is obvious that accurate potency tests should be carried out by the producer of the serum.

In the treatment of anthrax, serum should be administered in large doses. An animal showing only a high temperature, with no other manifestations of the disease, should be given from 30 to 50 c. c., but if the gravity of the disease is pronounced, 100 c. c. should be administered. In almost every instance a drop in temperature may be observed and a diminishing of the severity of the symptoms. At times, however, a relapse occurs about the second or third day following the serum injection, when it becomes necessary to administer another dose of serum. It has been proved that animals affected with anthrax, even after the bacilli are found in the blood circulation, may recover after an injection of potent serum.

The simultaneous treatment, as in the Pasteur treatment, may at times result in a temperature and systemic reaction in the animals. These manifestations are indicated by an elevation of temperature and sometimes by a swelling at the point of inoculation of the spore vaccine. These symptoms, however, are usually of short duration, and only in very exceptional cases will they result in the loss of the animal. However, if the reaction following the injection of the spore vaccine threatens the life of the animal, a second injection of serum should be administered.

The anthrax serum injected simultaneously with the vaccine has a counteracting effect upon the reaction which may follow the injection of the spore vaccine during the process of immunization.

At times anaphylactic reactions are observed as a result of the serum injected, especially in cases where the serum is foreign to the animals treated. These manifestations appear as a rule within one-half hour after injection, in the form of urticarialike eruptions, swelling of the head, slight chills, and rise in temperature. More severe symptoms have also been noted to follow such injections, but they almost invariably subside within a few hours.

TEST OF THE SIMULTANEOUS METHOD ON CATTLE AND SHEEP.

A series of experiments was conducted at the experiment station of the Bureau of Animal Industry at Bethesda, Md., to establish the efficiency of the simultaneous method of anthrax immunization on cattle and sheep.

For this purpose 6 head of cattle and 5 sheep were given the simultaneous injection of anthrax serum and spore vaccine. Three weeks subsequent to immunization they were subjected to infection tests which consisted of a subcutaneous administration of 0.25 c. c. for the cattle and 0.125 c. c. for the sheep of blood from a guinea pig which had died from an artificial infection with our most virulent strain of anthrax.

The microscopic examination of the blood of the guinea pig showed it to be heavily charged with anthrax bacilli, but in order to make the test as severe as possible it was deemed advisable to use such excessive amounts. Three additional cattle and two sheep were used as checks, receiving only the virulent blood. As a result of this infection all animals manifested an elevation of temperature ranging from 103° to 107° F. The control animals especially were markedly affected with typical manifestations of anthrax and all succumbed within two to eight days following infection. All but one of the vaccinated sheep succumbed to anthrax, but at a later date than the check animals. Of the immunized cattle a marked temperature reaction was noted, but all of these animals recovered with the exception of a small, undersized, weak calf, which died in six days following infection.

While in the above test the sheep succumbed and one of the small calves died of anthrax, nevertheless the potency of the serum was demonstrated. The excessive virulent blood used for the infection was extraordinary and could not be compared with the amount of virus taken by a susceptible animal in cases of natural infection.

FIELD TESTS.

On June 21, 1915, Dr. R. R. Ashworth, a dairy inspector for the District of Columbia, notified our office that a number of deaths among hogs were occurring on a farm in Maryland, just outside of the District. The symptoms described by Dr. Ashworth pointed suspiciously to anthrax. A visit was made to the farm the same morning, and after an autopsy on several animals, followed by a bacteriological examination, a definite diagnosis of anthrax was established. This was later conclusively verified by animal inoculation tests.

At that time 7 shoats and 4 sows had died of the disease and 3 shoats, 4 sows, and 1 boar were showing symptoms of anthrax, several of the

sick animals manifesting the characteristic edema of the throat region. It is desired to make particular mention of the boar, a fine pure-bred animal, which was in an almost comatose condition, showing a profuse bloody diarrhea, and a temperature of 106° F. One of the sows was also in a very critical condition.

On the afternoon of June 21 the affected animals were given injections of the immune serum, the boar receiving 100 c. c., the sows 50 c. c., and the shoats 30 c. c. On the following day a visit was made to the farm to immunize the remaining hogs, which as yet had shown no symptoms of the disease. A total of 138 were given protective doses of the serum, the larger hogs weighing 75 pounds or over receiving 10 c. c. and the smaller animals 5 c. c. Marked improvement was noted in the sick animals that had been treated the day before.

On June 23 another visit was made to the farm. All of the sick animals showed still further improvement. The boar was given 60 c. c. more of immune serum and the sow that had been the most sick was given an additional 30 c. c.

The result of this work was that every affected animal recovered, and up to the present time not a single death from anthrax has been reported in those animals that received protective doses of the serum.

In the early part of July an outbreak of anthrax was reported from Queen Anne County, Md. On July 13 two inspectors from the bureau were detailed to make an investigation, with a view to using our immune serum and spore vaccine in an effort to control the outbreak. The disease had made its first appearance about a month previous to this time, when a farmer lost a cow from anthrax. A few days later a neighbor on an adjoining farm lost a hog from the disease. Following this, the disease made its appearance on five other farms in the immediate vicinity, the greater percentage of animals stricken dying of the apoplectic form of the malady. Animals on some of the farms had been treated with single injections of a commercial vaccine before the arrival of our inspectors. Immunization tests were at once started with the bureau serum and spore vaccine, with the following results:

The animals on six farms where losses had occurred from anthrax were vaccinated, the cattle, horses, and mules receiving 10 c. c. each of serum and 1 c. c. of spore vaccine, except, however, in cases where there was reason to believe an animal might be in the incubative stage of the disease, when the vaccine was omitted and the dose of serum increased. Sheep and hogs on the infected farms were given the serum-alone treatment, receiving from 5 to 10 c. c. each.

On the day subsequent to vaccination a mule on one of the farms showed symptoms of anthrax, there being an elevation of temperature and a characteristic swelling on one side of the neck, the side

opposite to where the vaccine had been injected. This animal was given an injection of 60 c. c. of serum and made a speedy recovery.

In all, 399 animals, including horses, mules, cattle, sheep, and hogs on farms where the disease had broken out, were treated with the bureau serum and vaccine. Previous to this an aggregate of 10 cattle, 3 mules, and 13 hogs had died of anthrax on these farms. On the morning of the day following vaccination a cow on one of the farms died of anthrax. Exclusive of the above, no losses from anthrax have occurred on any of these farms.

Approximately 140 animals on several other infected farms were vaccinated with a commercial vaccine by a representative of the State live stock sanitary board. Within a day or two following this vaccination it was reported 3 cows and 1 mule died of anthrax, and since then 2 more cows have died of the disease.

Another opportunity was afforded us to test the serum and vaccine in an outbreak of anthrax in Noxubee County, Miss., where a number of farms were reported to be infected with the disease. A quantity of serum and spore vaccine was furnished, and an inspector detailed from the bureau station at Birmingham, Ala., to conduct the work. On various farms where the disease had made its appearance a total of 125 cattle were given the simultaneous treatment. In addition 3 animals which showed symptoms of the disease were given 30 c. c. of serum alone. No deaths from anthrax occurred immediately following or since the vaccination, the affected animals having all recovered from the disease:

USE OF SERUM IN TREATMENT OF ANTHRAX IN MAN.

Extensive data are available on the effectiveness of anthrax serum for the treatment of the disease in man. It is recommended that from 30 to 40 c. c. of serum be injected in three or four different places. Should no improvement follow in 24 hours an additional injection of 20 to 30 c. c. of serum should be administered.

In most instances the results are very favorable, and this treatment is acknowledged to be superior to any other mode of treatment known for this disease.

CONCENTRATION OF SERUM.

Experiments are now being conducted in drying immune serum with a view to preparing the same in pellet form. For this purpose the serum has been dried in shallow pans in a serum-drying apparatus. After thorough drying it is scraped from the pans, milled into a fine powder, and prepared in a pellet machine into proper-sized pellets. The spore vaccine is also being prepared in a similar

manner. This procedure would greatly simplify the administration of the serum and vaccine and, besides, the products would be in a form least likely to deteriorate or become contaminated.

The proteids containing the protective bodies of the serum have also been successfully precipitated through fractional saturation of the serum with ammonium sulphate, and further work along this line is now being conducted. However, this work and the work on the drying and concentration of the products are still in the experimental stage, and it is our aim to properly work out a method most suitable for immunization of animals in the field.

CONCLUSION.

1. Horses are suitable for the production of highly potent anthrax serum. Serum of such horses should protect large animals in 10 c. c. doses.

2. The use of the serum-alone treatment is indicated in cases where the infection has already occurred in a herd. Since the serum confers only a passive immunity, it is advisable to revaccinate the herd in from three to five weeks by the simultaneous method.

3. The serum possesses great curative value. Depending on the severity of the infection, the curative dose is from 30 to 100 c. c.; the injection to be repeated if necessary.

4. For the simultaneous treatment a spore vaccine, carefully standardized, is preferable to the ordinary Pasteur vaccine.

5. Spore vaccine should be employed also in preference to the Pasteur vaccines for immunization with vaccine alone. This vaccine has a decided advantage over the Pasteur, because of the possibility of more accurate dosing and because of its better keeping qualities.

6. Experiments with concentrated serum and dry spore vaccine are very promising. This method would greatly simplify the vaccination process and also insure the product against subsequent contamination and deterioration.

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SCENE ALONG THE BRANDYWINE, SHOWING TYPICAL CHESTER COUNTY TOPOGRAPHY.

UNITED STATES DEPARTMENT OF AGRICULTURE



BULLETIN No. 341



OFFICE OF THE SECRETARY

Contribution from Office of Farm Management

W. J. Spillman, Chief

Washington, D. C.

PROFESSIONAL PAPER.

January 17, 1916

FARM MANAGEMENT PRACTICE OF CHESTER COUNTY, PA.

By W. J. SPILLMAN, *Chief, Office of Farm Management*, H. M. DIXON, *Assistant Agriculturist*, and G. A. BILLINGS, *Agriculturist*.

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OBJECTS OF STUDY.

The objects of this study were:¹

1. To work out a method of studying regional farm management problems.
2. To discover fundamental principles of farm management.
3. To work out the application of these fundamental principles to the agriculture of a definite agricultural region.

It is believed the system of tabulating and interpreting farm-management survey data worked out in the study of the survey made in Chester County and presented in this bulletin offers a means of interpreting such data that will render such a farm-management survey of great value in determining the best agricultural practice in any distinct agricultural region.

¹ Acknowledgment is due Messrs. J. I. Falconer, D. L. Cottrill, H. B. Munger, L. G. Connor, Jos. H. Hamilton, E. L. Moffitt, and H. M. Doyle, who assisted in collecting the data presented in this bulletin. Prof. F. D. Gardner, of the Pennsylvania State Agricultural College, gave valuable assistance in selecting the area studied and suggestions concerning the conduct of the work. Thanks are extended to the many farmers in this region through whose courtesy this work was made possible.

NOTE.—This study is based on the operations of 643 farms in an old and prosperous agricultural section. It is designed to develop fundamental and broadly applicable principles of good farm management.

RESULTS.

The more important of the fundamental principles of farm management brought out clearly in this study, and amply confirming similar studies, are:

The type of farming followed in any given case must be adapted to local soil, climatic and labor conditions, and especially to local conditions with reference to markets and market facilities, as well as to the business conditions existing on the individual farm.

When the conditions affecting the agriculture of a region have remained stable for a considerable period local agricultural practice tends to become approximately what it should be for best results, provided the practice which gives the best immediate returns does not unfavorably affect soil fertility. When conditions change, even slightly, if the change is permanent, local farm practice begins to change and ultimately adapts itself to the new conditions.

Success in farming, measured in terms of the family income and standard of living, is directly proportional to the magnitude of the farm business, although the percent of profits on the farm investment is, within wide limits, independent of the magnitude of business. With the types of farming generally adapted to this locality many of the farms found in this survey are too small to permit a satisfactory standard of living.

In the matter of yield of crops per acre, the point of diminishing returns is reached on a considerable proportion of farms. Profits increase as yields increase until the yields are considerably above the average for the locality, but beyond this increased yields are obtained at the expense of farm profits.

In quantity of product per dairy cow, the point of diminishing returns is not reached in ordinary farm practice. Hence, on dairy farms, quantity of product per cow is, on the average, a more important factor of success in farming than yield of crops per acre.

It is both easier and more profitable to increase low acre yields than high ones, and a small product per cow than a large one. In other words, profits can be increased most easily by attention to the weakest points in a system of farming. The more vital the weakness the greater the increase in profits that can easily be made.

With a given type of farming, under given conditions, there is a certain way of dividing acreage among the several enterprises of the farm which is more profitable than any other way; that is, there is a most profitable acreage for each crop. Similarly there is a most profitable proportion of income from each source. If the acreage of any crop or the proportion of income from any enterprise be greater or less than this optimum, the profits of the farm as a whole are lowered thereby.

Certain enterprises may be distinctly profitable when occupying a minor position in the farm business and distinctly unprofitable if made major enterprises. This appears to be true of fruit growing in Chester County, and, to a less extent, of poultry keeping.

On small farms the expense of operation is much greater per unit of product than on large farms of similar type.

Diversity of the farm business is, as a rule, an important factor of success in farming. A medium degree of diversity, sufficient to give good seasonal distribution of labor, complete utilization of land, and a considerable variety of sale products, is better than either extreme diversity or a low degree of diversity.

The more important applications of the above principles to the agriculture of this survey area are given below. It is believed that most, if not all, of these conclusions are likewise applicable to a wide region in the Middle Atlantic States where similar conditions as to soils and markets prevail.

APPLICATION TO CHESTER COUNTY AGRICULTURE.

Most of the farmers in the region of this survey have developed systems of farming that are approximately what they should be to secure the best results, but a large minority have not. The results outlined below and discussed in detail further on should be of value to the majority in confirming their judgment and to the minority by showing them how their systems of farming may profitably be improved.

Briefly stated, these are the more important conclusions bearing directly upon the possible improvement of Chester County farming:

That the standard rotation of the section, namely:

First year.	Second year.	Third year.	Fourth year.	Fifth year.
Corn.	Corn. Potatoes. Oats.	Wheat.	Timothy and clover.	

should be changed thus:

First year.	Second year.	Third year.	Fourth year.	Fifth year.	Sixth year.
Corn.	Corn.	Annual hay crop. Potatoes.	Wheat.	Timothy and clover.	

That oats as grain are unprofitable here.

That the average Chester County farmer should grow a little more corn than he needs for home use.

That the total hay area (including annual hay crop) should occupy between 40 and 50 per cent of the land in crops.

That it does not pay to buy hay in this region, except where the cows kept are of the highest dairy type.

That dairying should normally be the leading enterprise, with about one cow to each 4 or 5 acres of crops grown.

That the average return per cow for dairy products is \$80, and that where receipts per cow are less than \$50 per year *the larger the herd the smaller the labor income.*

That more heifer calves should be raised.

That steer feeding is not worth while as a main line of business except on large farms where labor is scarce.

That a few hogs should ordinarily be fed for the market.

That the region is not well adapted to sheep farming.

That flocks of 100 to 150 hens are more easily made profitable than larger or smaller flocks.

That fruit and truck should be grown chiefly for home use.

That potatoes probably occupy about their proper place in Chester County farming.



FIG. 1.—Location of area surveyed.

That yields per acre can profitably be increased up to about 40 per cent above the average. After that the labor income falls off.

That labor income increases with the size of the farm, and that the average for farms of less than 40 acres is too low to keep up a good standard of living.

That farms where diversification is about the average for the section are usually more profitable than those where farming is either more or less diversified than the average.

TERRITORY SURVEYED.

Chester County, Pa., is situated in the southeastern part of the State, a short distance from Philadelphia, and near the city of Wilmington, Del. (See fig. 1.) The area in which this study was made lies in the southern portion of the county bordering on the States of Maryland and Delaware, as shown by the shaded portion of the map in figure 1.

This area was chosen for the following reasons: The soils of the area are extremely uniform in character, thus giving uniformity to the farm practice of the region and permitting comparisons to be made without the disturbing element of variation in type of soil; the region has long since passed the stage of pioneer farming; and the forces which control type of farming have had sufficient time to assert themselves and produce a highly stable agriculture, which now changes only when economic or other conditions change. The local agriculture therefore lends itself admirably to a study of the fundamental principles of farm organization.

In this study the business of 643 farms was analyzed, a record being made of the value of all farm property; the proportion of capital invested in land, buildings, live stock, implements and machinery, supplies, and cash for current expenses; the sources of income and the amount from each; the nature and amount of expenditures; and numerous other items bearing on profit in farming. Before entering upon the discussion of the data obtained from these farms it is necessary to consider the local geographic conditions which have a bearing on the local agriculture.

TRANSPORTATION FACILITIES AND MARKETS.

Figure 2 shows the survey area on a larger scale, in which are shown the transportation lines, the country roads, and the township boundaries. The dots on this map represent the situation of the farms studied in this survey. It will be observed that one line of railway passes through the area in a general easterly and westerly direction, near the center of the area, to Philadelphia, which is 38 miles from Avondale, near the center of the area. This is the main artery of commerce for the area. Another railroad runs through Avondale in a general northerly-southerly direction. This is a crossroad connecting main roads which run north and south of the survey area, but it carries some milk to Philadelphia by way of its connection to the north. There is another railway bordering the northeastern boundary of the area over which some milk is shipped to Philadelphia.

A trolley line begins at West Grove, near the center of the area, and passes eastward through Avondale and Kennett Square, then southeastward to Wilmington, Del. This trolley carries a considerable quantity of milk to Wilmington. From Kennett Square another trolley line runs north and then northeast to West Chester, the county seat of Chester County, which lies 4 miles from the edge of the area. This line is devoted almost wholly to passenger traffic. Wilmington, Del., lies 15 miles to the southeast of Avondale, while Baltimore, Md., lies 65 miles to the southwest. A few truck farmers in the area haul their produce by wagon to Wilmington.

It will be observed that the area is well covered with country roads, though these are laid out quite irregularly. Several stretches of these roads have been macadamized. Others are fairly well graded and ordinarily in good condition, though many of the roads are poor.

By far the most important industry in the county is the production of market milk. Practically all the farms studied are less than 5 miles from a shipping point. Kennett Square is the largest village, but has little effect on the local agriculture. Its population is about 2,000.

There is practically no relation between types of farming and distance from shipping point in this area, since all the farms are fairly



FIG. 2.—Map of survey area. Farms surveyed indicated by dots.

close to a shipping point. The principal type of farming, namely, production of market milk, is one which, by proper cooperation in delivering the product to the shipping station, is within rather wide limits little influenced by distance to the shipping point. In the absence of collective delivery of milk, distance to shipping point becomes a very important matter.

TOPOGRAPHY AND DRAINAGE.

Figure 3 shows the topography of the area surveyed. The heavier shading represents the higher land, the shading decreasing in density toward sea level. The lowest elevation is found in London Britain

township at the south edge of the area and along the Brandywine River at the northeastern edge. In these two localities the elevation is less than 200 feet above sea level. The highest portion is in the northwestern quarter where the land rises somewhat more than 600 feet above sea level. The greatest difference in elevation to be found in the area is thus somewhat over 400 feet. When it is remembered that in some good agricultural regions differences as great as this are found on a single 200-acre farm it will be seen that the topography here is not at all rough and broken. The uplands are rolling,

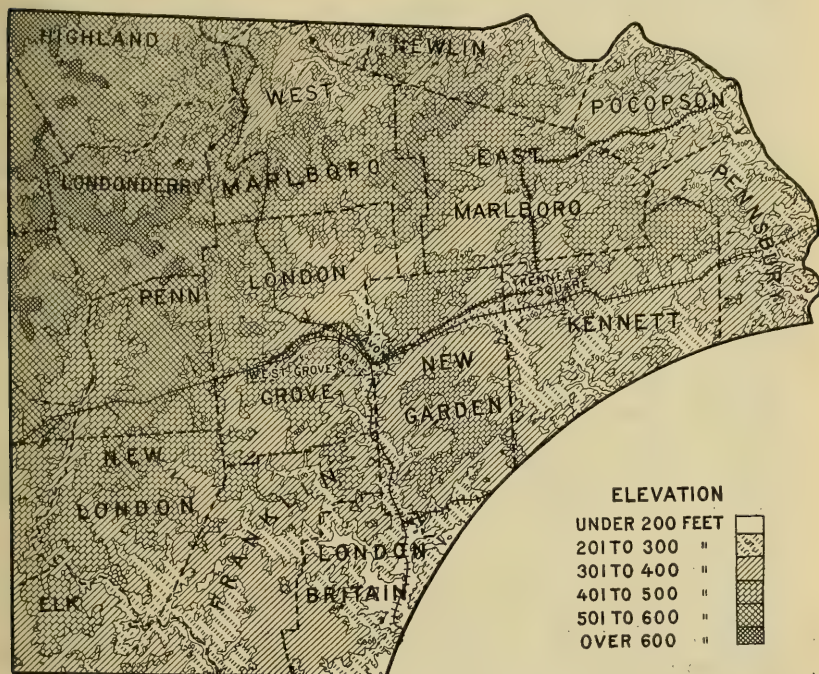


FIG. 3.—Topography of area surveyed.

resembling somewhat the surface of the bluegrass area of Kentucky, though the unevenness of the surface is more marked and is cut by many streams, frequently with steep, wooded slopes. (See frontispiece.) In the western portion of the area the land is in some cases steep enough to cause more or less washing, especially where fall-plowed land is left bare during the winter. In general, however, the topography is rolling, the natural drainage being excellent except along the stream bottoms, which are generally in permanent grass. (See Pl. II.) It is seldom necessary to resort to artificial drainage on the farms in this area. Never-failing springs are found on nearly every farm, and the well-kept pastures are thus abundantly supplied with water. Some of the streams are utilized for power by means of

overshot wheels, the principal use of this power being for pumping water to the farm buildings. In the early days many of the lowland pastures were irrigated. Some of the old trenches can still be seen.

SOILS.

Figure 4 represents the distribution of the principal soil types of the surveyed area. It will be observed that the Chester loam is by far the most important soil in the region, followed by the Manor loam. These two soil types occupy nearly the whole area, there being scattered here and there small patches of other types. This area was selected partly because of unusually uniform soil conditions. The elimination of important soil differences makes it possible to study other factors of profitableness in farming to great advantage.

The Chester loam is described by the Bureau of Soils as a silty loam, which means that it is somewhat heavier and more compact than an ordinary loam soil. The soil is, on the average, about 10 inches deep, having a smooth texture with little coarse grit except in the subsoil. The Manor loam, the next most important soil type, differs from the Chester loam mainly in containing more coarse, micaceous material. It is also somewhat less productive.

The soils of this area have in general been formed by the disintegration of granitic rocks, which are deficient in lime, though in a few places there are limited areas of limestone outcrop. The soils are not naturally highly fertile, though when properly managed they may be made distinctly so.

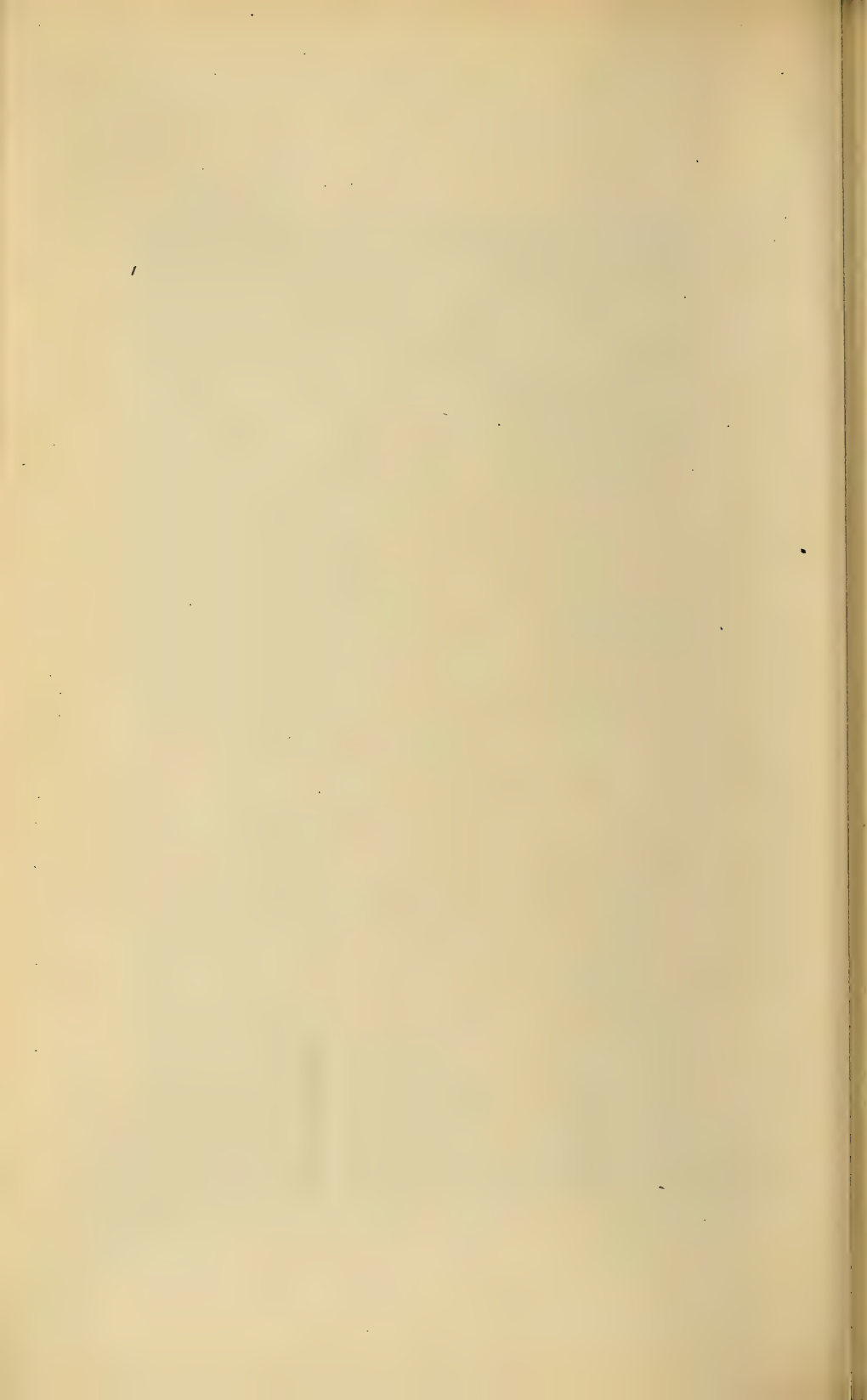
The pastures consist almost entirely of Kentucky bluegrass, and are remarkably productive when the deficiency of lime in the soil is considered. Their productivity is, in the main, due to the rather heavy character of the soil and to the excellent care taken of the pastures (see fig. 4). In this area farmers manure and lime their pastures frequently, and it is not uncommon to find pastures, especially those in the stream bottoms, with a carrying capacity of one cow per acre.

AGRICULTURAL HISTORY.

Records of the early agriculture of Chester County are meager. The county was established by law in 1682 and was formally organized in 1685. It was then an important agricultural area, the county seal selected in 1683 bearing a plow in recognition of its agricultural character. Indeed Chester County has always been noted for its progressiveness in agricultural matters. Some of the first American plows and hay-cutting implements were invented



DAIRY HERD ON PASTURE LAND ALONG THE BRANDYWINE.



and manufactured here, and there is still a factory making certain kinds of farm machinery at Kennett Square.

Until some time after the Revolutionary War there were no well-established and well-recognized rotations practiced by the farmers. The soil had originally been covered by timber, and it was customary to clear out an area of this, crop the land mainly to corn, wheat, rye, barley, and garden crops for a series of years until the yields became very low, when new land would be cleared and the old land left to grow up in grasses, which were used for pasture.

During the closing years of the eighteenth century a system of crop rotation began to be established, a good deal of enthusiasm hav-

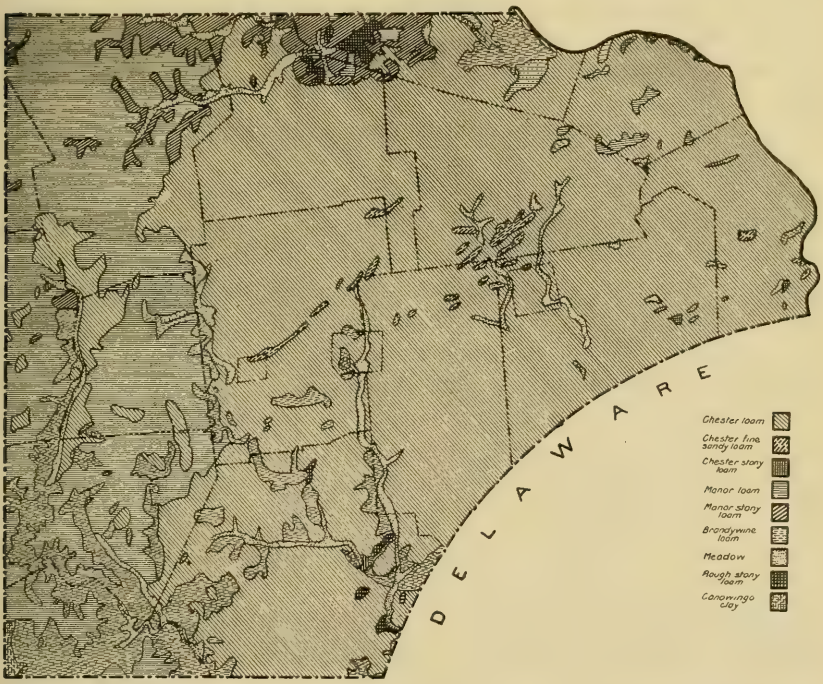


FIG. 4.—Soil map of survey area. (From report of Bureau of Soils, U. S. Department of Agriculture.)

ing been aroused for it, and much was said and written about “the new way of farming.” Thus in 1796 a Chester County farmer, writing to a friend in England, said: “Where we had Indian corn the year before is dunged by spreading this broadcast and planted to barley, oats, and flax. * * * Barley ripens about July 20, flax sooner, and oats later. We plow again in August, and sow to wheat and rye in September. * * * We sow clover the following March.” It will later be seen that this is essentially the rotation which is now practically universal in this region, the only change being the sub-

stitution of corn and potatoes for the barley and flax of the second year and the addition of timothy to the clover at the end of the rotation.

An article in the *Farm Journal* in 1853, written by a Chester County farmer, describes essentially the same rotation in the following words: "The rotation is (1) corn on sod; (2) oats; (3) wheat; (4) clover and timothy mown or pastured; (5) hay; (6) hay; (7), (8), and (9) pasture." Further on in the article, referring to the oat crop, the writer remarks: "If it were convenient to plant wheat after corn, this crop would probably be dispensed with."

Thus the cropping system which is now standard in the county had its beginning about 125 years ago. It was not at all general, however, until about 1820, about which time clover became a universal crop in the county, though this crop had been introduced from Lancaster County as early as 1756.

A CHANGE IN THE LOCAL AGRICULTURE.

In the late forties (1845-1850) the agriculture of the North Atlantic States suffered a severe depression. About this time there was a marvelous extension of agriculture into the Ohio and the Mississippi Valleys. Improvements in agricultural machinery were taking place rapidly. The most important of these was the invention of the reaper. About the same time great improvements were made in plows, haying machinery, and thrashers.

As a result of these improvements the average farm family was able to farm a much larger area. For this reason the farms established in the West were larger than those of the older settled portions of the East, and production on them was less costly. The small farms of the East were not in position to compete with the larger farms on the rich soils of the West.

Table I gives some idea of the profound changes that occurred in eastern agriculture during this decade. At the beginning of the decade swine were the most numerous farm animals in Chester County, there being 64,500 of them. By 1850 their number had fallen to 36,600. The second most important animal, from the standpoint of numbers, was sheep. This industry suffered more severely than the swine industry, the decrease during the 10-year period being from 56,700 to 13,400. In 1840 Chester County had 45,000 cattle, exclusive of dairy cows. These were mainly beef cattle. But the county was unable to compete with the West in the production of beef, and the industry declined rapidly, the decline continuing till 1890, at which time cattle other than dairy cows had decreased to 12,000 head. Since that time there has been some increase in these cattle.

TABLE I.—*Census data showing changes in the agriculture of Chester County.*

Live stock and crops.	1840	1850	1860	1870	1880	1890	1900	1910
Dairy cows.....	16,000	19,604	25,900	32,700	42,400	49,300	45,700	45,400
Other cattle.....	45,000	35,500	29,900	21,100	18,400	12,000	21,700	19,700
Swine.....	64,500	36,600	31,500	28,200	34,000	35,600	30,500	21,400
Sheep.....	56,700	13,400	11,700	13,100	15,100	11,200	9,900	5,300
Milk sold (thousands of gallons).....				1,598	5,759	24,000	17,038	20,206
Butter produced (thousands of pounds).....		2,092	2,730	2,848	4,247	1,628	1,314	573
Wheat (thousands of bushels).....	438	547	801	754	775	882	785	928
Barley (thousands of bushels).....	45	2	5	1.6	.9	.2	.2	1.2
Oats (thousands of bushels).....	1,080	1,146	1,227	1,034	1,137	868	925	777
Rye (thousands of bushels).....	86	52	32	12	20	19	22	27
Corn (thousands of bushels).....	826	1,339	1,590	1,540	1,965	1,959	2,687	1,882
Hay and forage (thousands of tons).....	78	96	94	115	126	162	131	142

There were 16,000 dairy cows in Chester County in 1840. The numbers increased rather rapidly till 1890, since which time there has been a slow decrease, due mainly to a decrease in the area of improved land and to scarcity of farm labor. In 1840 dairy cows were kept mainly for production of home supplies and a small amount of butter for sale. In 1850 slightly more than 2,000,000 pounds of butter were produced. This production increased until about 1880, having doubled in this time. Since then the amount has decreased to less than one-seventh of the former maximum.

About 1870 the city of Philadelphia began reaching out into Chester County for market milk, the county supplying 1,600,000 gallons in that year. From 1870 to 1890 this industry increased enormously, reaching 24,000,000 gallons in the latter year. Since that time the business has decreased slightly, owing mainly to the decrease in the area of improved land. Corn has always been an important crop in this region, being second only to hay in acreage. Its relative importance is increasing. Wheat follows corn in acreage and has maintained about its present status for the past century.

Oats were formerly an important crop, but since 1890 there has been a gradual decrease, until at the present time they occupy only half the area of wheat in the county as a whole and only one-third in the surveyed area.

Hay has always been important and its production increased steadily to 1890. During the next 10 years it decreased considerably, mainly because of the decrease in the area of improved land.

There has been a gradual increase in potato production in Chester County since its early history, though the crop has never been an important one.

Previous to 1840 rye and barley were important crops in the county. Barley practically disappeared during the panic of the forties. Rye decreased steadily until 1870, since which time there has been a slow increase, though it is still an unimportant crop.

The production of clover and grass seed was an important industry in Chester County in 1840, but gradually declined and practically disappeared about 1890.

About 1880 a tobacco furore broke out in the county. For a few years the area increased enormously, having spread from the adjoining county of Lancaster. But the craze for tobacco lasted only a few years. Prices were disappointing and the prejudices of the farming people against the crop militated against its continuance. In the area surveyed tobacco was found on only three farms, two of them being tenant farms.

FARMS CLASSIFIED BY TENURE.

Of the 643 farms included in this survey 449 were operated by their owners, 17 were operated by farmers who owned part of the land and rented additional land, and 7 were operated by owners who rented out a part of their farms. There were 57 tenants paying cash rent, 75 paying a half share, and 14 who furnished only labor and received one-third of the products of the farm. There were three other tenants who rented land from more than one landlord and 21 of the records were incomplete and were hence discarded.

The 449 farms operated entirely by their owners were subdivided as follows: 378 farms on which the farmer himself took a man's part in the work of the farm; 16 farms owned and managed by women who did none of the farm work; 27 farms devoted wholly or in part to a hothouse business, mainly mushrooms, though in two cases carnations were grown; 1 owner received more than half of his income from business not connected with his farm; 24 farms were either operated by hired managers who received a salary or were owned by physicians or other professional men who are not really farmers but who maintain country homes; finally, there were 3 small truck farms whose owners bought and sold additional truck-crop products.

A careful examination of the tabulations in the following pages will show that the comparisons on which this bulletin is based could not well be made between the various groups mentioned above. The work is therefore limited to the 378 farms operated by owners who took full part in the work of the farm, except where otherwise noted in the text.

Brief reference is made to the 27 farms maintaining a hothouse business, and there is also a somewhat extended discussion concerning two of the classes of tenant farms mentioned above.

SIZE OF FARM AND UTILIZATION OF LAND.

Table II shows the sizes of farms found in the surveyed area, the number in each size group, and the manner in which the land is utilized. The farms were first grouped into the sizes shown in the

first column of Table II. It will be observed that the number of farms is nearly uniform in the various size groups up to farms of 120 acres. Beyond this the numbers drop off so rapidly that in order to secure numbers sufficient for reliable averages it was necessary to use wider size limits in the groups. The average size of farms in the various groups ranges from 28 acres in the smallest to 203 in the largest, the average of the 378 farms being 90 acres. Of this, 71 per cent is tillable and 61 per cent actually devoted to harvested crops. Ten per cent of the entire farm area is represented by pasture on tillable land, 11 per cent by pasture on untillable land, 9 per cent by woodland, while the remaining 9 per cent represents waste land, roads, building sites, etc.

TABLE II.—*Size of farms, utilization of land, value of real estate, percentage of pasture, and crop and pasture area per animal unit, 378 Chester County farms operated by their owners.*

Sizes of farm in acres.	Number of farms.	Average size.	Tillable area.	Crop area.	Tillable pasture.	Other pasture.	Woodland.	Waste land.	Value of real estate per acre.	Pasture. ¹
		<i>Acres.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>		<i>Per ct.</i>
13 to 40.....	54	28	75	67	8	9	5	11	\$123	21
41 to 60.....	61	52	72	62	10	10	8	10	94	24
61 to 80.....	60	73	72	63	9	11	7	10	94	24
81 to 100.....	68	93	71	62	9	10	10	9	91	23
101 to 120.....	52	110	71	60	10	12	8	10	86	27
121 to 160.....	61	136	66	58	7	13	11	11	84	26
161 to 393.....	22	203	73	53	14	10	11	7	87	29
All sizes.....	378	90	71	61	10	11	9	9	90	25

¹ Per cent pasture is of total crop and pasture area.

The proportion of tillable land is approximately the same on farms of all sizes, being somewhat smaller on the larger farms, though in the very largest group it is above the average. The per cent of crop area decreases as the size of farm increases, ranging from 67 per cent of the entire farm in the smallest group to 58 per cent in the largest. The pasture area increases slightly with increase in size of farm, as does also the woodland. The percentage of waste land is about the same on all the groups except the largest, where it is somewhat smaller than the average.

The last column of this table shows the percentage of the combined crop and pasture area consisting of pasture. This increases considerably on the larger farms, ranging from 21 per cent to 29 per cent and averaging 25 per cent.

The preceding column shows the value per acre of the real estate in 1911, the year to which this survey relates (more accurately, Mar. 1, 1911, to Mar. 1, 1912). The average for the entire 378 farms was \$90. With the exception of the last group, consisting of the largest farms in the area, there is a gradual and considerable decrease in

price per acre with increase in size of farm, due largely to relatively greater cost of buildings on the smaller farms. There is a slight increase in the last group as compared with the preceding one, due largely to the fact that a considerable number of these large farms are owned by wealthy men who have had the capital to secure choice land, and install somewhat elaborate equipment. Since that time there has been a marked increase in the price of land in this section.

The reason for the general prevalence of farms of small to moderate size in this region is largely historical. These farms were established at a time when improved farm machinery was not available and when in consequence the ordinary farm family could farm only a small area. At that time farmers produced practically all their food and clothing, and they produced very little surplus for the markets. Under such circumstances only a small proportion of the population could live in cities, for the farm population could not feed such multitudes as are found in our modern cities. When competition with the West brought on the panic of the forties, it became necessary for the farmers of the North Atlantic States to increase the magnitude of their business in order to meet the competition with these larger farms of the West. There were two methods of doing this. One was to secure more land; the other was to farm more intensively. Most eastern farmers chose the latter because it represented the line of least resistance.

In locations favorable to fruit and truck growing these industries developed enormously in this general region. So great became the production, especially of vegetables, that the business was gradually crowded off of all except the most favorably situated areas of very light soil, which could throw their products on the market very early in the season and thus get the advantage of the high prices which prevail before the markets are overstocked. The business, therefore, became practically impossible on the heavier types of soil. The only other methods of developing intensive farming were dairying, poultry raising, and tobacco growing. Several localities in the North Atlantic States particularly adapted to the production of high-grade tobacco have developed this business extensively. One of the important tobacco-growing areas is in Lancaster County, just west of Chester. Poultry are found on practically all farms in the North Atlantic States, and here and there over this entire territory are many farms devoted mainly to this business.

But the type of intensive farming available to the largest number of eastern farmers was dairying, and this whole region has become one of the most intensive dairy regions on the continent. This was the course taken by the farmers of Chester County, dairy products constituting by far the most important source of income.

TYPES OF FARMING.

One of the worst mistakes a farmer can make is to choose unwisely the enterprises that are to constitute the basis of his farm business. The swiftness with which disaster overtakes the man who makes a serious mistake of this kind causes the rapid elimination of types of farming wholly unfit in a given locality, so that, at least in the older sections of the country, we seldom find types of farming distinctly unsuited to their surroundings. But serious errors of this kind are made on a large scale in certain regions which are now undergoing settlement, and in others where real estate promotion schemes are based on the utterly false assumption that merely because the soil and climate of a region are adapted to the most intensive types of farming all the land can be devoted to the production of the most intensive crops without reference to the possibility of marketing the products.

In all sections of the country changes in economic or other conditions sometimes render well-established types of farming unsatisfactory, and it becomes necessary for farmers to make more or less radical changes in their practice. Attention has already been called to the changes in the eastern States which began about 1840, and which involved the practical destruction of the eastern sheep industry and a very great reduction in the importance of beef cattle and swine in the same region.

Another example of the effect of changes in economic conditions necessitating changes in type of farming is seen in the gradual transfer in recent years of the butter-making industry from the Eastern States to the Middle West. In the latter region, because of the larger size of the farms, the greater natural fertility of the soil, and the more general use of labor-saving machinery, grains and forage can be produced more cheaply than in the North Atlantic States. Early in the history of the Middle West the quantity of grain and forage produced made feedstuffs very cheap, and especially in the northern portion of the region the production of butter gradually became one of the leading industries. In some localities, especially in Wisconsin, cheese making also became a dominant enterprise. Butter and cheese can be shipped to eastern cities at relatively small expense. Under these conditions the makers of butter and cheese in the Eastern States found themselves hard pressed by the competition from the West. A severe depression followed, and even yet the price of farm land in the East is only just beginning to reflect the better times that succeeded with the general development of the market-milk industry incidental to the enormous growth of eastern cities. Both butter and cheese making have been largely transferred to the West during the past third of a century.

Such marked changes in type of farming as have just been mentioned practically never occur except as the result of a permanent change in economic or other conditions affecting the profitableness of types of farming. Since the market-milk business rose to prominence in the area here under consideration agriculture has remained remarkably stable, and the types of farming found are, in the main, those adapted to the prevailing conditions. Occasionally, however, a farm is found on which a wrong type has been undertaken. This is because the forces which determine type of farming are not generally understood. Even when most of the farmers of a region are following the types of farming they should follow, it is not clearly understood that this is the case, a statement the truth of which is proved by the fact that a considerable proportion of the farmers in almost every locality have undertaken things that are well-nigh impossible under their conditions. Now a farm-management survey may be made to show what types of farming are producing the best results in the region surveyed. As will appear later, the results set forth in this bulletin indicate quite clearly what local practices are most profitable, at least in many cases. These results should be useful to those who are already following the best practice by confirming their judgment and thus preventing possible departure from the best practice through lack of knowledge of what is best. It should help those who are making mistakes by pointing out to them wherein they are in error.

The conclusions reached in this bulletin concerning cropping systems and types of farming best suited to the conditions of this region will undoubtedly apply to a much wider area than that from which they are directly drawn—in short, to practically all localities in this general region in which similar conditions prevail.

Type of farming is determined by the enterprises which constitute the basis of the farm business; that is, by the crops grown, the live stock kept, etc. But since the importance of an enterprise depends on the income from it, it is customary to classify farms according to sources of income. Ordinarily, when any one enterprise produces as much as 40 per cent of the income of a farm, the farm is said to belong to the type represented by that enterprise. Relatively few farms have this large a proportion of income from a single enterprise, so that in most cases it is necessary to mention more than one source of income in describing the type of a particular farm. The farms in the area here under consideration will be considered, first, from the standpoint of the crops grown; second, from the standpoint of the live stock kept; and, third, from the standpoint of the amount of income from different sources.

CROPS.

The type of cropping system which is most general in Chester County consists of a rotation beginning with corn the first year. The second year is usually divided between corn and potatoes or oats and potatoes or corn and oats or corn, potatoes, and oats. Wheat occupies the third year, and is followed by grass, usually timothy and clover, which is ordinarily cut for hay for two years before the sod is broken up for corn, though local practice differs considerably as to the number of years the grass is left down. There are, of course, numerous modifications of this general scheme. These will be discussed later. The actual acreage of each of the more important crops on the 378 farms operated by their owners is shown graphically in figure 5. The same data are shown in percentages in Table III. Hay is seen to occupy twice the area of corn, its closest competitor. Wheat is third, occupying 18.2 per cent of the total crop area: oats

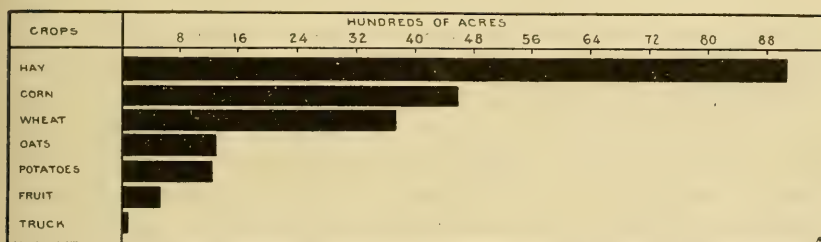


FIG. 5.—Acres of the more important crops on 378 Chester County (Pa.) farms operated by their owners.

are fourth, with 6.4 per cent, and potatoes are fifth, with 6 per cent. Fruit is grown on 2.5 per cent of the cropped land. In this survey no account was taken of kitchen gardens. These probably occupied about one-third as much land as the orchards. The farmers of this region grow garden vegetables very generally in sufficient quantity for home use. The truck-crop acreage given in Table III represents commercial truck crops, which are seen to be of relatively small importance in this area.

That the area included in this survey is fairly representative of Chester County as a whole is shown by the census data for the entire county given in the third column of Table III. Potatoes and hay are a little more important in this area than in the county as a whole, while oats are somewhat less important. Commercial truck crops, special crops, especially tobacco, and miscellaneous crops occur somewhat more frequently in other parts of the county than they do in the locality of the survey.

TABLE III.—*Percentage of crop area devoted to each crop; 378 Pennsylvania owners.*

[Illinois survey data and Chester County census figures included for comparison.]

Crop.	Total crop area.		
	378 Penn- sylvania owners.	Chester 1910 census figure.	73 Illinois owners.
	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
Total corn.....	22.3	22.1	53.9
Potatoes.....	6.0	4.8	(a)
Wheat.....	18.2	18.0	18.7
Oats.....	6.4	9.9	18.9
Total hay.....	44.0	39.0	7.3
Fruit.....	2.5	2.8	.....
Truck.....	(a)	.3	.....
Special crops.....	(a)	.6	.....
Miscellaneous crops.....	.3	2.0	1.2
Total.....	100.0	100.0	100.0
Total tilled crops (field).....	28.3	26.9	53.9
Total small grain.....	24.7	28.7	37.6
Total hay.....	44.0	39.0	7.3

a Less than one-half of 0.1 per cent.

The reasons why these various crops occupy the places they do in the agriculture of this region will be discussed in some detail in another portion of this bulletin.

For the sake of comparison, the percentage area is given in Table III for the various crops on a group of Illinois farms included in a survey and reported in Bulletin 41 of this department.¹ Wheat is the only crop which occupies a similar status in the two localities. In the corn-belt area corn occupies more than twice the area it does in Chester County. This is not so much because corn is so much better adapted to the western locality; in fact, the yield of corn per acre is considerably higher on the Pennsylvania farms than it is on the Illinois farms. It is due rather to the fact that economic conditions in the western locality are not so favorable to other crops as they are in the East.

The most striking difference between the two regions is the difference in the relative acreage of hay. Hay does just as well in Illinois as it does in Pennsylvania, but economic and other conditions are not so favorable for its production. In the first place, beef cattle and hogs, which are the dominant productive live stock in the Illinois area, consume much less hay than do dairy cattle, which are the dominant type in Chester County. In the second place, the price of hay in the West is much less than it is in the East. We have here an excellent illustration of the fact that conditions other than soil and climate must be taken into consideration in determining what crops the farmer should grow.

¹ A Farm-Management Survey of Three Representative Areas in Indiana, Illinois, and Iowa, 1914.

Miscellaneous crops.—The special and miscellaneous crops referred to in Table III were as follows: Corn for soiling, 36 farms, with an average of about 1 acre each; sweet corn, 9 farms, with 1.2 acres per farm; millet, an average of 3 acres on each of 35 farms; oat hay, 22 farms, with an average of 3.25 acres; alfalfa, 18 farms, with an average of 4.8 acres each, a total of 78.75 acres of this crop. Since this survey was made the area of alfalfa has increased considerably in this locality. A small acreage of each of the following crops was found on from one to six farms each: Rye, peas and oats, millet and rye, oats and rye, peas, barley, kafir corn and peas, and wheat, all for hay; for grain, rye, barley, and a mixture of oats and spelt; for seed, timothy, clover; tobacco, 5 acres on one farm; for soiling, rye, oats, peas and oats; for forage, beets on six farms and turnips on one farm; one-half acre of broom corn on one farm.

In a locality where there is much difference in type of farming on different farms, it is usual for the smaller farms to be devoted to the more intensive types of farming, though intensive enterprises may also occur on farms of any size. By an intensive enterprise is meant one which requires a relatively large amount of labor and capital for its conduct. Vegetable growing, fruit culture, and the hothouse business are intensive enterprises. Poultry farming is an intensive type of live-stock farming. Dairying is relatively intensive compared with sheep and beef-cattle farming. It may assume quite an intensive form, as when a large herd is maintained on a relatively small farm.

Aside from the hothouse business, which was found on 27 farms in this survey, there is relatively little intensive crop farming in this area. The reasons for this will be given later. On the remaining farms there is not much difference in type of farming on farms of different size. This is largely due to the predominance of dairying; the few farms having no dairy cows do not affect materially the averages of the various size groups.

The percentage area of the various crops on farms of different size is shown in Table IV for the 378 owner farms. The total percentage of corn acreage is about the same in each of the groups. The proportion of corn cut for silage increases noticeably on the larger farms, but this is due to the larger number of cows on these farms, not to any difference in type of farming.

The percentage of potato acreage is smaller on the large farms than on the small ones, but the actual acreage of this crop is larger on the large farms. The acreage of potatoes does not increase in the same ratio as the size of farm. The percentage of wheat acreage is remarkably uniform in the various size groups. This merely shows how firmly this crop is established in the local agriculture. It furnishes the needed straw for bedding, and acts as a nurse crop for the

more important hay crop. Only 22 of the entire number of owner farms—378—grew no wheat in 1911.

TABLE IV.—*Per cent of area in various crops by size of farms on 378 owner farms, Chester County.*

Acre groups.....	13 to 40.	41 to 60.	61 to 80.	81 to 100.	101 to 120.	121 to 160.	Over 160.	All farms.
Number of farms.....	54	61	60	68	52	61	22	378
Corn.....	23.7	22.1	20.5	19.6	20.4	18.2	18.3	19.8
Silage.....	.6	.2	1.3	2.0	3.0	2.8	5.7	2.5
Total corn.....	24.3	22.3	21.8	21.6	23.4	21.0	24.0	22.3
Potatoes.....	7.9	8.5	5.8	6.8	5.9	4.9	4.9	6.0
Wheat.....	17.4	18.9	19.5	18.3	17.6	18.3	16.9	18.2
Oats.....	4.8	5.3	6.3	6.7	6.1	6.4	7.5	6.4
Hay.....	39.9	40.2	44.3	43.8	42.7	47.2	44.6	44.0
Fruit.....	3.7	3.0	2.2	2.3	3.8	1.9	1.5	2.5
Truck.....	1.5	1.4	.1	.1	.2	.1	.3	.3
Special ^a		.2						
Miscellaneous ^b	.5			.4	.3	.2	.3	.3
Total.....	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

^a Tobacco.

^b Millet, rye, etc.

The percentage of oats increases slightly as the size of farm increases. This is because the smaller farms can ill afford to devote their scant acres to so unprofitable a crop. The owners of the larger farms can afford to indulge their fancy for this excellent but usually expensive horse feed. As will be pointed out later, it would probably pay to replace oats by an annual hay crop in this region.

The percentage of hay acreage increases slightly with increase in size of farm. Hay is one of the most salable crop products produced in this region and brings excellent prices. Hay is also a crop which requires relatively little labor. The smaller farmer devotes more of his land to crops that give him more days' work per acre. The larger farmer already has enough field work to keep him busy and can hence afford to put a larger proportion of his land in hay.

Farms that carry a very large complement of live stock in this region put more of their land in corn and less in hay than those having less stock. They, of course, sell less hay, and the greater area of corn saves buying a corresponding amount of concentrated feeding stuffs.

The fruit orchards of this region are almost entirely for home use. The actual acreage is about the same on farms of all sizes, which accounts for the gradual decrease in percentage area with increase in size of farm.

Very little commercial vegetable growing is done in this area. What little is done, however, is seen to occupy a greater percentage area on the smaller farms, which is in keeping with the general tendency for small farms to be conducted more intensively than larger farms. If truck farming were well adapted to this area, there would undoubtedly be more of it, especially on the smaller farms.

LIVE STOCK.

The dairy cow is by far the most important farm animal in the Chester County area. This is shown very clearly in figure 6 and in Table V. Figure 6 shows the average number per farm of animals and animal units of each of the various classes.¹ There is an average of nearly 11 milk cows per farm for the 378 farms operated by their owners.

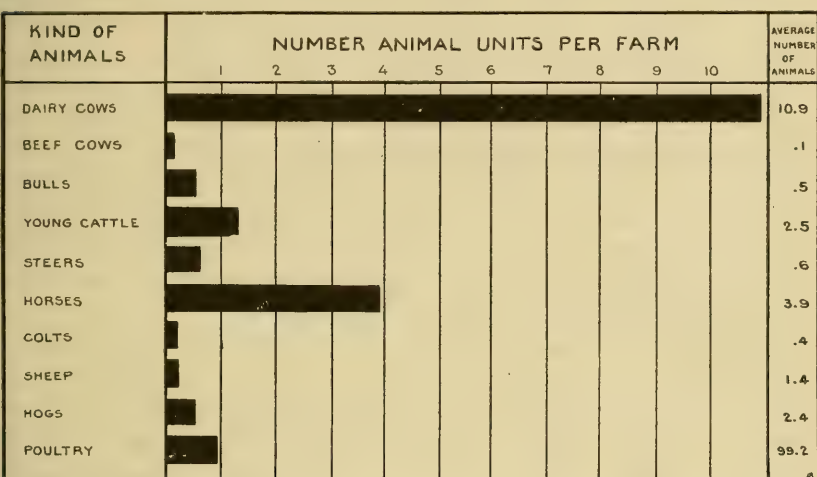


FIG. 6.—Number of animal units per farm; 378 Chester County (Pa.) owner farms.

TABLE V.—Distribution of animals and animal units on 378 owner farms, Chester County.

Kind of live stock.	Average number of animals.	Total animal units.	Per cent of total animal units.
dairy cows.....	10.9	10.9	56.2
beef cows.....	.1	.1	.5
bulls.....	.5	.5	2.6
young cattle.....	2.5	1.3	6.7
steers.....	.6	.6	3.1
horses.....	3.9	3.9	20.1
colts.....	.4	.2	1.0
sheep.....	1.4	.21	1.1
hogs.....	2.4	.6	3.1
poultry.....	99.2	.99	5.6
		19.3	100.0

The number of young cattle is only about one-fourth that of mature cows. Since in order to keep up both numbers and quality in dairy herds it is necessary to keep about 50 per cent as many young stock as mature cows, it is clear that Chester County farmers are not raising sufficient young stock to keep up their herds. It will later be seen that the major portion of the cows are bought. The reason for this is that the production of market milk is the dominant

¹An animal unit is a mature horse or cow or as many smaller animals as require the feed of a horse or cow, namely, 2 head of young cattle, 5 hogs, 7 sheep, or 100 hens.

type of dairying in this region, which leaves no skim milk for the young stock. Farmers have felt that they could buy cows more cheaply than they could be raised on the high-priced milk available. In general this has been true until quite recently, but in recent years the prices Chester County farmers have had to pay for cows have risen until at the present time raising has become at least as cheap as buying. Since this survey was made (1911-12) many more calves have been saved by these farmers than formerly, and the proportion of cows bought is now less than it was a few years ago. This has an important bearing on the question of herd improvement. It is a very difficult matter to buy cows of high quality, and high productive capacity on the part of the dairy cow, as will later be shown, is one of the most important problems confronting Chester County farmers.

The horses kept on Chester County farms are mainly work animals. Less than one farm in three raises colts. Horse raising is thus not an important feature of the local farming, and the practice of buying western horses to feed for sale, which is common in some Central Western States, is here practically unknown.

Excepting dairy cattle and horses, poultry are the most important farm animals. The average number of hens per farm is almost exactly 100, or 1 animal unit. The status of poultry as a farm enterprise in this region will be considered in detail later. Nearly every farm keeps some poultry, but there are very few real poultry farms.

A few hogs are kept on most farms, but the absence of skim milk, together with high local prices for grain, makes the hog a relatively unimportant enterprise here. Hogs are kept mainly for home supplies, though some farmers realize considerable cash income from this source.

Beef cattle and sheep were found on only a few farms each. Most of these were farms where labor was scarce and difficult to obtain.

Table VI shows the acres per animal unit for each of the size groups. Taking the live stock as a whole, there is about the same intensity of stocking in each group, the average acres of crops per animal unit being 3.47 and the acres of pasture 1.18. The average area of crops per dairy cow is 4.89 acres. The area of pasture per animal unit increases quite markedly with increase in size of farm. This is to be expected, since the larger the farm the less intensive the farming must be for satisfactory results.

The heaviest stocking with dairy cows is found in the 41 to 60 acre group and in the 101 to 120 acre group. The reason for this will be brought out later. The two largest groups have relatively fewest cows per given area of crops, or, what is the same thing, relatively the largest acreage of crops per cow.

TABLE VI.—Intensity of live-stock farming on 378 owner farms, Chester County.

Size of farms in acres.	Number of farms.	Average area.	Acres per animal unit.		Crop acres per cow.
			Crops.	Pasture.	
		Acres.			
13 to 40.....	54	28	3.41	0.88	4.82
41 to 60.....	61	52	3.37	1.08	4.46
61 to 80.....	60	73	3.45	1.10	5.02
81 to 100.....	68	93	3.58	1.08	4.93
101 to 120.....	52	110	3.31	1.23	4.31
121 to 160.....	61	136	3.61	1.27	5.20
160+.....	22	203	3.39	1.41	5.44
All sizes.....	378	90	3.47	1.18	4.89

The relative intensity of the various live-stock enterprises on farms of different size is shown in more detail in Table VII. Except in the case of bulls and colts, this table gives the number of animal units per hundred acres of crops.

TABLE VII.—Average number of animal units per 100 acres of crops for different kinds of live stock on 378 owner farms, Chester County.

Kind of live stock.	Size of farms in acres.							All farms.
	40 or less.	41 to 60.	61 to 80.	81 to 100.	101 to 120.	121 to 160.	Over 160.	
Dairy cows.....	20.3	21.2	19.1	19.7	23.2	19.2	18.4	20.4
Beef cows.....	.5	.3	.8	.5				.3
Young cattle.....	1.6	2.3	2.0	2.3	2.3	2.4	2.6	2.4
Bulls ^a	.1	.4	.4	.6	.8	.7	.8	.5
Steers.....	.1	.3	2.3	.5		.8	4.6	1.2
Horses.....	11.2	8.9	7.7	7.2	6.8	6.2	6.3	7.2
Colts ^a	.1	.3	.5	.4	.4	.7	.6	.4
Sheep.....		.1	.1	.2	.8	.4	.7	.4
Hogs.....	1.6	.9	.4	.9	.9	2.0	1.2	1.1
Poultry.....	4.5	2.7	2.5	2.1	1.5	1.4	.7	2.0

^a Number of animals per farm.

Attention is called to the fact that farms of 41 to 60 acres and those of 101 to 120 acres are relatively more heavily stocked with dairy cows than are farms of other sizes. This is believed to be due to the fact that the first of these two groups represents farms of about the proper size for one-man dairy farms, while the second is made up of farms about the proper size for two-man dairy farms. Evidence of this will appear in other tabulations.

The number of hens per farm is approximately the same for each of the size groups. For this reason the number per hundred acres of crops decreases in about the same proportion that size of farm increases.

The number of horses increases slightly as the size of farm increases, but not in the same proportion, so that there is some decrease in the number per hundred acres of crops on the larger farms.

The cattle reported as beef cows in Table VII are really dairy cows which are not milked but which are utilized in raising calves bought from near-by dairy farms that dispose of their calves at

birth. Only a few such herds were encountered in this survey, and they produced very poor returns to their owners. They were mostly on farms where labor for the care of a dairy herd was wanting.

On each of the 378 owner farms of this area herds of dairy cows numbering up to about 25 were found to be fairly common. One herd of 55 and another of 80 cows were found. There were a good many very small herds, especially on the smaller farms. The young stock, which are incidental to the dairy herd, are not nearly so numerous as they should be in order to maintain the herds.

The number of bulls is about the same on farms of all sizes, but a larger proportion of the larger farmers own their bulls. In a good many cases bulls are owned in partnership, or a farm may keep a bull only part of the year. This accounts for the number of cases of less than one bull per farm. Only four farms were found having more than one bull.

Forty-two steers were found on one farm and 39 on another. Three other farms had from 20 to 24. On 19 farms 10 or fewer steers were present. Three other farms had fed a few steers during the year but had none on hand either at the beginning or the end of the year. Three of the five largest herds of steers were found on farms belonging to the largest size group. The other two were on farms which are somewhat too large for one-man exclusive dairy farms and too small for two-man farms of this type.

One or more colts were found on 112 of the 378 farms, the largest number on any one farm being 4. Several farms had colts either at the beginning or at the end of the year, but not both, which accounts for the cases of less than one colt. About 3 farms in 10 raise colts in this area.

Small flocks of breeding ewes were found on 14 farms. Only three of these kept sheep other than the breeding flock.

Brood sows were found quite generally, but in no case did the number exceed six. There was very little relation between the number of brood sows and the size of the farm. On the other hand, the larger farms fed more hogs than the small ones.

Poultry were found on almost every farm, but the flocks seldom exceeded 100 hens. The largest flock consisted of 600.

SOURCES OF INCOME AND PERCENTAGE OF RECEIPTS FROM EACH.

Very few farms in the locality here under consideration can be classified as belonging to any single type other than dairying. Of the 378 farms operated by their owners, 157 obtain more than 40 per cent of their income from dairy products alone, to say nothing of the receipts from the sale of calves and discarded cows. The region is thus distinctly a dairy region, though we shall find a considerable degree of diversity in the local farming.

The sources of income¹ on the 378 farms found in this survey, together with the proportion of receipts from each source, are given

¹ DEFINITIONS.—A number of terms which are used in the discussion which follow are more or less technical in character. These are defined below.

The *gross income* of the farm is the sum of the receipts from all sources. The *net income* is the difference between the gross income and the farm expenses. In cases where no confusion is likely to arise from so doing, the net income will frequently be referred to simply as the *farm income*; but where reference is made to income without qualification as to gross or net the gross income is usually meant. The context will always make clear the exact meaning intended.

In most kinds of business the net income is referred to as the *profits* of the business, and this is usually expressed in percentage of the capital invested. The term "profits" is used in this sense especially in those cases in which every one connected with the business receives a salary. In such cases the net income is profit on the capital invested. But, in farming, the head of the business usually receives no salary; in this case the net income represents both interest on capital and the wages of the operator.

In dividing the net income between interest on capital and wages of the operator there are clearly two ways of procedure. We may subtract the value of the farmer's labor from the net income, and call the remainder the profit on capital. But there are very distinct advantages in dealing with the profits in farming in a different way. It will be found more advantageous to assume a rate of interest for capital invested, usually the current rate on well-secured farm loans, subtract the amount of this interest from the net income, and call what is left the *labor income* of the farmer. By using this labor income as the measure of efficiency in farming it will be seen that many useful comparisons can be made that would not be possible in any other way. In this bulletin it is assumed that capital is entitled to 5 per cent interest, and this figure is used except where otherwise stated.

Adjusted labor income.—It will later be shown that the amount of the labor income depends largely on the magnitude of the farm business, and this in turn depends on the size of the farm, especially in the case of farms similarly organized and devoted to the same type of farming. Since on the great majority of farms in the Chester County (Pennsylvania) survey area the type of farming is quite similar, the size of the farm is the principal factor in determining the amount of the labor income. But in many cases it is desirable to study the effect of factors other than size of farm. That is, it will frequently be desirable to divide the whole number of farms into classes without reference to size, and to determine the relation between labor income and the basis on which the farms are grouped. This can be done very satisfactorily in many cases by using what in this bulletin is termed the *adjusted labor income*. This is a modification of labor income in such a way as to eliminate the influence of size of farm. The method is as follows: The farms are first divided into groups based on size (area); the average of the labor incomes in each size group is then calculated; the labor income of each farm in a group is then expressed in percentage of the average labor income of the size group to which that farm belongs. Thus, the average labor income in the 61 to 80 acre group of farms operated by their owners (see Table XXIII) is \$730. On one of these farms the labor income was \$584, or 80 per cent of the average for the group. The adjusted labor income of this farm is thus 80 per cent, or simply 80. In some of the tables the adjusted labor income is calculated in dollars, but in most cases it is expressed merely in percentage of the group averages. A very small farm having a labor income 80 per cent as great as the average of farms of similar size and type is regarded as being as efficient as a large farm having a much greater labor income, but which is 80 per cent of the average of the size group to which the larger farm belongs. It will be found that the use of this adjusted labor income permits many important comparisons that could not otherwise be made.

Some writers on farm management limit the term *profit* to what is left of the net income after deducting interest on capital and wages for the farmer. This is clearly a use of the term inconsistent with the usual practice in the business world, but at the same time it serves to make a useful distinction. In this bulletin, however, the word "profit" is used in its more usual sense, and frequently, where the meaning intended is clear, the labor income will be referred to as the profit of the farm. This is done to avoid frequent repetition of longer phrases, but it is believed no confusion will result, since the context will always show exactly the meaning in which the term is used.

In this bulletin the 27 farms devoted either entirely or partly to the production of hot-house products are referred to as *special farms*; the 378 farms operated by their owners are usually referred to as *owner farms*; and the 124 farms operated by tenants are called *tenant farms*. Except where otherwise specifically stated, the discussions in this bulletin relate to the 378 farms operated by their owners.

in Table VIII. The same data are shown in graphic form in figure 7. In the case of potatoes it should be remarked that the price of this commodity for the year to which this study relates (1911-12) was very high, and this gives the crop a much greater apparent importance than the facts justify. On the face of the returns for this year the potato crop occupies third place as a direct source of revenue. Under average conditions it would stand fifth or sixth in the area to which this study relates. This fact should be kept in mind in interpreting the data given here.

TABLE VIII.—*Proportion of income from various enterprises on 378 Chester County farms operated by their owners and 73 Illinois farms.*

Sources of income.	Per cent of total.	
	378 Pennsylvania farms.	73 Illinois farms.
Dairy products.....	39.1	0.9
Dairy cattle.....	5.0	2.2
Beef cattle.....	1.5	23.6
Horses, mules, and colts.....	.4	5.2
Sheep.....	.5	.3
Hogs.....	2.8	28.4
Poultry and eggs.....	8.2	1.9
Miscellaneous receipts ^a	1.9	.5
Increase in feed and supplies.....	4.1	2.0
Corn.....	2.3	19.3
Potatoes.....	8.9	(b)
Wheat.....	8.5	10.7
Oats.....	.2	3.7
Hay.....	14.3	.4
Fruit.....	.7	.0
Truck.....	.5	.0
Miscellaneous crops.....	1.1	.9
	100.0	100.0

^a Labor, outside the farm, wood sold, etc.

^b Less than 0.1 per cent.

Taking the community as a whole, we find dairying occupying the place of greatest prominence. If we add together the receipts from dairy products and those from the sale of calves and dairy cows, this industry is found to account for more than three times as great a proportion of the income on these farms as any other enterprise. Hay stands second, while wheat and poultry represent other important sources of income. Ordinarily potatoes stand on a par with dairy cattle here. The remaining enterprises which are of sufficient magnitude to be represented on the scale of figure 7 are hogs, corn, steers, straw, fruit, truck, sheep, horses and colts, and oats, in the order named.

For the sake of comparison with a region where economic conditions are vastly different from those prevailing in Chester County, similar data are given in Table VIII for the group of Illinois farms previously mentioned. In this Illinois area the most important source of income is hogs, the percentage of income from them being

ten times as great as it is in the Chester County area. Beef cattle are nearly as important as hogs in the corn-belt area, and sixteen times as much as in Chester County. As has already been seen, the percentage of corn acreage in the Illinois area is more than twice as great as it is in the Chester County area. The Chester County farmer grows a great deal of corn, it being his second most important crop. But he uses most of this corn on the place. Many of the Illinois farmers sell their corn, mostly to neighbors who feed their own as well as their neighbor's corn to hogs and beef cattle. Corn is thus the third largest source of direct income in the western area, while in the eastern one it stands eighth. Wheat is the only source of income of approximately equal importance in the two localities.

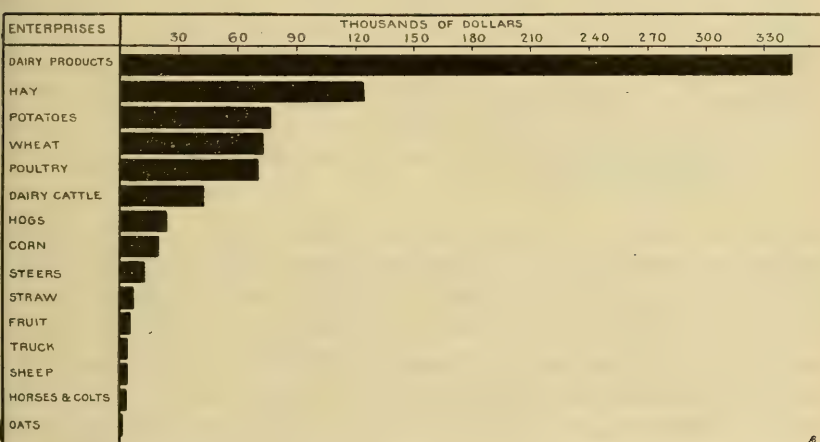


FIG. 7.—Sources and amount of receipts on 378 Chester County (Pa.) owner farms.

MISCELLANEOUS SOURCES OF INCOME.

In addition to the sources of income mentioned in Table VIII, the number of other farm products found here and there on a few farms is very small in the Chester County area. They are as follows: Seven farms sold a little corn fodder; five sold a little sweet corn; average of \$22 worth of chestnuts were sold from two farms; two sold an average of \$21 worth of rye; and the following products constituted a source of income on one farm each: Sweet peas, \$300; cornstalks, \$50; tobacco, \$616; millet, \$84; clover seed, \$90; timothy seed, \$110; and broom corn, \$24.

The relation of sources of income to size of farm is shown in Table IX. The proportion of income from dairy products increases slightly till the group of farms of 101 to 120 acres is reached. The two larger groups derive somewhat less of their income from this source than the last-named group.

TABLE IX.—Percentage of receipts from different sources, by size of farms, on 378 Chester County farms operated by owners.

Size of farms in acres.	13 to 40.	41 to 60.	61 to 80.	81 to 100	101 to 120.	121 to 160.	Over 160.	All farms.
Number of farms.....	54	61	60	68	52	61	22	378
Source of income:	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
Dairy products...	28.9	33.1	35.9	38.0	48.1	39.5	40.5	39.1
Dairy cattle.....	4.9	6.4	5.8	5.7	3.3	4.8	4.4	5.0
Beef cattle.....	.2	.1	2.5	.8	.0	1.8	4.8	1.5
Horses.....	.1	.3	1.4	.1	.2	.5	.3	.4
Hogs.....	4.5	2.8	1.2	2.8	2.6	3.8	2.3	2.8
Sheep and wool...	.0	.1	.1	.3	.9	.4	1.1	.5
Poultry and eggs.	18.7	11.6	11.7	8.5	6.0	6.4	3.3	8.2
Corn.....	1.2	2.5	2.5	2.1	2.3	2.2	3.1	2.3
Potatoes.....	9.3	12.4	8.6	11.0	8.2	6.9	7.5	8.9
Wheat.....	5.8	8.2	9.4	8.4	8.5	9.0	8.0	8.5
Oats.....	.2	.2	.2	.1	.1	.2	.3	.2
Hay.....	9.6	10.0	13.4	13.6	12.4	18.4	16.9	14.3
Fruit.....	1.4	1.3	1.0	1.0	.6	.2	.2	.7
Truck.....	3.0	1.8	.1	.1	.2	(d)	.4	.5
Special ^a	.7	.7						.1
Miscellaneous ^b	5.1	4.2	3.1	3.9	1.7	1.9	2.7	2.9
Feed and supplies ^c	6.4	4.3	3.1	3.6	4.9	4.0	4.2	4.1

^a Sweet peas, 1 farm; tobacco, 1 farm.^b Miscellaneous crops (rye, millet, straw, etc.), labor, lumber, or wood sold, etc.^c Increase in inventory.^d Less than 0.05 per cent.

It will be noticed that the largest increase between two successive groups is between the 81 to 100 acre group and the next larger, while the second largest is between the 13 to 40 acre group and the 41 to 60 acre group. As previously stated, there are indications in much of the data collected in this survey that the 41 to 60 acre farms are approximately the proper size for a one-man dairy farm in this locality, while the 101 to 120 acre farms appear to be about the proper size for a two-man dairy farm. Dairying is therefore relatively slightly more important in these two groups than in the others. The third group (61 to 80 acres) is slightly too large for a one-man farm and yet not large enough for a two-man farm, as ordinarily organized. In this group wheat, hay, and beef cattle are all somewhat more prominent sources of income than the position of these farms in this table calls for. Being rather large for a one-man exclusive dairy farm, some of these farms are conducted on a less intensive plan. The percentage of income from wheat in this group is the largest of that of all the groups, while the income from beef cattle is relatively larger than in any other group except the last, consisting of the largest farms found in the survey.

The 81 to 100 acre group of farms approaches nearer the proper size for a two-man dairy farm, and many of them are thus organized. The two groups of largest farms, being somewhat too large for two-man exclusive dairy farms, are on the average conducted in a somewhat less intensive manner, beef cattle becoming more prominent in the last group than in any other. Sheep are also most prominent in

group. Hay is more prominent as a source of direct income on two groups of largest farms than on any others.

In a general way, with some exceptions, beef cattle, sheep, and hay decrease in relative importance with increase in size of farm, though increase is slight and rather irregular. These represent the less intensive enterprises. But the more intensive enterprises, such as poultry, potatoes, fruit, and truck crops, decrease in relative importance as the size of the farm increases. In the case of poultry, the total income is approximately the same in each of the size groups. The same is true of the income from fruit. In the case of potatoes, the actual income increases slightly with increase in size of farm, while in the case of truck crops it decreases.

We have already seen that the percentage of wheat acreage is remarkably uniform in the different size groups. With the exception of the very smallest farms, on which the small quantity of wheat grown is largely used for chicken feed, the percentage of income from wheat is quite as uniform. Except in the first group, there is only one group in which the figures vary more than one-half of 1 per cent from the average of 8.5.

The number of farms other than dairy farms in this area is too small to permit definite conclusions concerning the relation of size of farm to type of farming; but if we compare the average area of the farms deriving as much as 20 per cent of their income from the various enterprises, we get the interesting result that the 106 farms deriving as much as 20 per cent of their income from the sale of hay average 105 acres in area. This is considerably higher than the average of 60 acres for the whole number of farms. Likewise the 10 farms deriving more than 20 per cent of their income from steers average 108 acres, and the two deriving this much of their income from sheep average 108 acres. These are the less intensive enterprises and tend to gravitate toward the larger farms. On the other hand, farms deriving as much as 20 per cent of their income from the more intensive enterprises average as follows: Poultry, 51 farms, 56 acres; potatoes, 39 farms, 78 acres; truck crops, 4 farms, 33 acres. These facts are all in keeping with the principle that the smaller the farm the more intensive must the farming be for best results, provided, of course, the region is one in which the more intensive enterprises can be made successful.

The foregoing data relate entirely to the 378 farms operated by the owners and not maintaining a hothouse business. There were 10 of the latter, their average size being 62 acres. Several of them are farms of less than 40 acres, but there is an occasional large farm which runs a mushroom plant as a side line, though in some cases it represents the principal source of income even on these large farms.

It is a business which may be made successful on a very small area, but which may also constitute part of the business of a farm of any size. This is generally true of very intensive enterprises.

CROP AREA AND CROP RETURNS IN RELATION TO LABOR INCOME.

The farmer has often been told that he should keep careful cost-accounting records as a means of determining what enterprises are the more profitable, thus enabling him to increase the magnitude of the more profitable enterprises and eliminate unprofitable ones, thereby increasing his net profits. Many farmers have undertaken to do this, but in many cases the results were such as to be contrary to the farmer's better judgment, and the attempt was often abandoned. We shall here see that this doctrine is more or less of a fallacy. The actual cost of conducting a farm enterprise can not be arrived at by ordinary bookkeeping methods. The profit a farmer makes is not infrequently due to the fact that his business is based partly on enterprises that the usual methods of cost accounting would show are conducted at a loss. The fact is that the real cost of a farm enterprise depends not on the labor and materials devoted to its conduct, but, in part at least, to its relation to the other enterprises maintained on the same farm. Thus, on a farm which produces corn and hay as its principal field crops most of the equipment and labor required for producing wheat are already at hand and would not be fully utilized if wheat were omitted from the rotation. Under such conditions a limited area of wheat might add to the profits of the farm, even if cost accounts showed that it returned less than the current rates of wages to the grower.

Similarly, a small flock of hens on the farm will find much of their living in insects, weed seeds, and the grain that would otherwise go to waste about the place. The time devoted to them may be largely that of women and children, who would otherwise not be earning anything. The materials used in constructing the quarters in which they are housed may consist largely of scrap lumber picked up here and there, and which would otherwise have no value. Under such conditions a small flock of hens may add materially to the profit of the farm when cost-accounting records would show them to be a losing proposition. But the story is a different one when the flock becomes so large that it can not be fed largely on waste materials and when the time devoted to it is time that could otherwise be employed at profitable productive labor.

As will be seen in what follows, there appears to be, under given conditions, a most profitable magnitude for many of the enterprises of these farms. Within certain limits, which can usually be ascertained by farm-management survey methods, a farm enterprise may

add materially to the profits of the farm business, while if the enterprise be made either smaller or larger than this the profits are reduced. Generally speaking, the farmers in the older settled agricultural sections have arrived at this optimum magnitude for the various enterprises they maintain on their farms. But they have done this in response to the action of obscure economic forces which are not clearly perceived. Hence many of them make mistakes in the matter of the relative magnitude of the enterprises they maintain. One of the most important lessons to be learned from a study of the kind reported in this bulletin is the position each enterprise should occupy on the farms of a given locality for best results. *In order to be able to determine this point, however, it is necessary that the survey include a large number of farms, and that these farms may be separable into large groups in which approximately the same mixture of farm enterprises occurs on all the farms within the same group.*

The adjusted labor income, of which use is made in the following tabulations, has already been explained. (See footnote, p. 25.) It has been calculated in such a way as to eliminate, as far as possible, the effect of magnitude of business on the labor income. Within a given region magnitude of business probably has more influence in determining the profit made by the farmer than any other one factor. In order to study the influence of less important factors satisfactorily, it is therefore desirable to eliminate this one. It would also be highly desirable to eliminate the factors of yields of crops per acre and income per animal unit, which are the next most important in studying such minor factors as percentage area of each crop, percentage of income from each enterprise, etc., but the number of farms available for this study is not large enough to permit this.

In some of the tabulations it will be seen that a relatively slight change in the percentage area of a given crop, or in the percentage of income from a given enterprise, appears to make a very decided difference in the profits made by the farmer. In some cases this difference is too great to be accounted for merely by the difference in crop area or in percentage income under consideration. This is particularly true in the case of the relation between percentage of income from fruit and labor income. (See p. 40.) A very slight increase in percentage of income from fruit amounting to less than 1 per cent of the total amount of income from these farms is accompanied by an increase of 18 per cent in the average labor incomes.

The reason for this is probably not because of the additional profits secured from the sale of fruit, but because in the main it is only the better class of farmers who take any care of their fruit and who go to the trouble to market the small surplus of this com-

modity they produce. They are thus better farmers all round than the others, and for this reason make much better labor incomes.

It must not be assumed, however, that this reason accounts for the results in all these tabulations. There is no reason for believing that the actual conclusions in any case are different from what they should be because of this effect. The results are simply magnified by it. In general the better farmers of the community do not depart widely from the average practice of the community, but the very fact that this is true is of itself evidence that in the case of most enterprises there is a normal status, departure from which interferes with the efficient management of the farm.

Thus those farmers who have 30 to 39 per cent of their crop acreage devoted to corn make greater profits than those having more or less than this. Similar conditions are shown for the other crops. It appears that the more alert farmers in this region have recognized at least to a considerable degree, the status which each of their enterprises should occupy for the best results. These men are, in general, better farmers than their neighbors.

It must not be concluded, however, that an unusual acreage of one of the important crops of the region is without influence on profit. There is undoubtedly a balance between the enterprises of the farm; a status of each enterprise which fits best into the local system of farming. Wheat, although not a highly profitable crop here, has its place in the system. It furnishes straw for bedding and offers opportunity for seeding the more important and more profitable hay crop. It also occupies the time of farm laborers and teams and utilizes farm equipment at seasons of the year that would not otherwise be fully occupied. Hence, although the crop is less profitable per acre than corn or hay, a certain percentage of acreage devoted to it makes the farm more profitable than if the crop were omitted.

That the conclusions drawn in the following pages concerning the most profitable status of each of the enterprises are, in the main, correct is strongly indicated by the three cases in which these conclusions indicate that the average practice of the community is not in keeping with the highest profit, or at least was not during the year of this survey. The first of these cases relates to the acreage of the corn crop.

The average per cent of corn acreage for the 378 farms is 22.3 of the total crop area. Table X indicates that the most profitable acreage is between 30 and 39 per cent. The most progressive farmers in this locality all agree that more corn should be grown locally than is grown, and a good many of them have in recent years let corn occupy two whole years in their rotations. Census data show that the relative acreage of corn has been increasing in recent years in Chester County. It will be remembered that about a decade and a

half ago the price of corn rose about 50 per cent in this country, and has remained at this level ever since. It is probable that under the old conditions the farmers of Chester County had come to the proper acreage of this crop, but with corn at its new high level of prices a larger percentage of corn acreage would be justified. Census data thus show that the farmers are slowly responding to the slight economic forces tending to force them in the direction of higher profit. The data of Table X indicate that the direction in which they are moving, as shown by census returns, is actually in the direction of higher profit, while the opinion of the best local farmers agrees both with the indications of Table X and of the census returns.

Another instance in which local practice is not consistent with the highest profits, as indicated in Table XIV, relates to the percentage of oats acreage. This table indicates that those farmers who grow no oats make much higher profits than those who devote a portion of their land to this crop. The best local farmers agree that the oat crop is not profitable here, and 140 of the 378 owners grow no oats. Furthermore, census statistics show that the relative acreage of oats in this county is slowly decreasing.

The other case relates to the percentage of potato acreage and the proportion of the farm income derived from this crop. In both cases the data collected in the survey show that the more important the potato crop on the farm the higher the profit, and the tabulations indicate that the limit of profit in this direction is not reached by local practice. Yet most of the farmers of this region state that they do not consider potatoes distinctly a profitable crop. They grow them largely to fill in certain vacant places in the labor schedule. But during the year to which this survey relates these farmers sold their potatoes at an average price of \$1.04 a bushel. The inference from the data is that if potatoes sold at this high price regularly, the percentage of acreage devoted to potatoes in this region should be much larger than it is now. The fact is, however, the average price of potatoes here, as elsewhere, is very close to the cost of production, and there is every reason for believing that the farmers are right in their opinions concerning the value of this crop.

The fact that the tabulations to be discussed presently lead to conclusions which are thus in agreement with the opinions of the more progressive of the local farmers, *even when these conclusions are not in agreement with average local practice*, and the further fact that good reasons can be given for the changes called for by the tables, give great weight to the conclusions drawn from the assembled data.

While data are not at hand to prove it, it seems probable that the status which a crop should occupy for best results in a system of farming would depend on the yield of that crop per acre. A crop which yields well on a given farm compared with other crops should

probably occupy a larger acreage than the same crop on another farm where it yields poorly in comparison with other crops. It is also probable that in two localities similar in all respects, except that in one the crops produce low yields while in the other the same crops produce good yields, the optimum status of the individual crops would be different in the two regions. Conclusions based on studies in one region should certainly not be applied too broadly in other regions in which conditions are different.

Corn.—We have already seen that on the average the corn crop occupies 22.3 per cent of the entire crop area in the area here under consideration. Percentages as low as about 13 and as high as about 33 are fairly common, the extremes being 8 and 55. The more frequent percentages of this crop are from 18 to 25. While the corn crop is nearly universal on these farms, and in a large number of cases occupies from one-fifth to one-fourth of the crop area, there is seen to be considerable variation in the percentage of corn acreage on the different farms. The question arises, What percentage of corn acreage is most profitable under the conditions which prevail in this locality? The answer to this question will depend to some extent on the intensity of the stocking of the farm. In general, those farms which are most heavily stocked have the largest percentage of their land in corn. But we may first consider the matter from the standpoint of the average conditions prevailing in the region.

Table X classifies the 378 farms into groups based on the percentage of their crop area devoted to corn.

TABLE X.—*Percentage of crop area in corn as related to labor income.*

Per cent of crop area in corn	0 to 19.	20 to 29.	30 to 39.	40+.
Number of farms.....	138	188	42	10
Adjusted labor income.....	94	102	121	52

Average percentage of corn area on the 378 farms, 22.3.

It will be noticed that the average labor income of the 138 farms having from 0 to 19 per cent of corn acreage is 6 per cent below the general average of the region. One hundred and eighty-eight farms had 20 to 29 per cent of corn acreage, and their labor incomes are 2 per cent above the average. In the next higher group 42 farms have an average labor income 21 per cent above the general average. Unfortunately, the number of farms in the next group is small, but it will be noticed that the average labor income on them is very low.

It will be remembered that the original form of the common rotation of this region had corn the first year only. In recent years the price of corn has risen very materially as compared with two decades ago, and corn has begun to invade the second year of the

rotation. On some farms it is beginning to occupy the whole of the first two years. The greatest number of farms is in the group next below that which appears to be the most profitable. But the farmers here are increasing the percentage of their corn acreage very materially, as an examination of the census statistics for the last two census years will show. In other words, the farmers are slowly responding to the economic pressure tending to drive them toward a more profitable cropping system than that which now generally prevails.

The average percentage of corn area for the entire number of farms (22.3 per cent) is in the group of Table X next below the most profitable one. This study confirms the opinion of the most progressive farmers of this region to the effect that they ought to increase their acreage of corn.

As previously stated, corn is here grown mostly for feed. But a considerable number of farmers grow more of it than they need for this purpose, selling a small surplus. Does it pay to do this? Would it pay better to sell all their corn, for which they can get very good prices, rather than feed it to the classes of live stock kept on these farms?

It was found that 127 of the 378 owners sell some corn. In fact, this crop constitutes the direct source of 2.3 per cent of the entire receipts of the 378 farms. In nearly all cases where corn is sold, the percentage of income from it is less than 20, and in only two cases is it more than 26. In the greater number of cases it is less than 10 per cent.

Table XI shows that the 251 farms that sell no corn make an average labor income considerably less than the 121 farms that derive from 1 to 19 per cent of their income from this source.

TABLE XI.—Percentage of income from sale of corn as related to labor income.

Per cent of income from sale of corn	None.	1 to 19.	20+.
Number of farms.....	251	121	6
Adjusted labor income.....	95	113	55

It evidently pays to sell some corn. Unfortunately, the number of farms in the next higher group is too small to give a decisive result, but it is significant that the average labor income of these six farms is exceedingly low. Apparently, it also pays to feed a part of the corn.

Potatoes.—On the farms here under consideration 6 per cent of the crop area was devoted to potatoes. They were found on 366 of the 378 farms operated by their owners. This crop is, therefore, very general in this region, though the acreage is usually small. In by far the larger number of cases the acreage, expressed in percentage of

total crop area, was found to be less than 10 per cent, which means less than 6 acres per farm. On only 7 farms was the percentage of potato acreage found to exceed 20 (or 12 acres). The farmers of this area do not generally regard potatoes as a profitable crop, though they grow at least enough for home use and usually some for sale. The yield is low, the average being only about 79 bushels. The principal difficulty is in the character of the soil, which is rather too heavy for best results with this crop. The price also fluctuates greatly, and on the average is little more than sufficient to cover the cost of production. Yet the crop helps to fill the labor schedule, and when kept within proper acreage limits probably adds somewhat to the profits of the farm business in the average year. During the year to which this survey relates the average price at which the farmers sold their potatoes was \$1.04, which is much above the normal. With prices like this the tabulated figures show that the farm profits increase both with increase in acreage of potatoes and in proportion of receipts derived from their sale. It is certain, however, that this does not represent normal conditions for this area, and hence the tabulations are omitted.

One of the defects inherent in the survey method of studying farm-management problems lies in the fact that unless conditions are normal at the time of the survey the results may be misleading. This difficulty can be overcome in a number of ways, one of which is to repeat the survey in the same locality for a sufficient number of years to establish a normal for each enterprise. Fortunately, however, conditions were approximately normal in this area at the time these data were obtained except in the matter mentioned, and in the fact that the price of hay was somewhat above normal. In the main, therefore, the results are reliable.

Wheat.—Wheat occupied 18.2 per cent of the total area of crops on the 378 owner farms. This crop occurred on 356 farms. In most cases the percentage of wheat acreage fell between 15 and 25 per cent, but on several farms it was greater or less than these limits. The average proportion of income from the sale of wheat was 8.5 per cent of the total farm income, as shown in Table VIII. In relatively few cases did a farm receive more than 20 per cent of its income from this source.

The most profitable acreage of this crop is shown in Table XII. The labor incomes of the 28 farms having less than 10 per cent of wheat acreage was much lower than the average of all farms.

TABLE XII.—Percentage of crop area in wheat as related to labor income.

Per cent of crop area in wheat.....	0 to 9.	10 to 19.	20 to 29.	30+.
Number of farms.....	28	213	121	16
Adjusted labor income.....	63	107	97	96

The 213 farms having 10 to 19 per cent of wheat acreage made profits considerably above the average. In the next higher group there are 121 farms, sufficient to give an average having a definite meaning. Their labor incomes averaged 10 per cent lower than in the preceding group. In the remaining group the number of farms is small, and they need not be considered. The results for the first, second, and third groups are apparently conclusive. They indicate that an acreage of wheat equal to 10 to 19 per cent of the total crop area is more profitable on these farms under normal conditions than either a larger or a smaller acreage. This merely means that wheat should here occupy one year in the rotation. But it appears to be more profitable to run wheat twice in the rotation than to omit it altogether.

It is interesting to note that not only is the largest number of farms in this most profitable group, but the average for the 378 farms falls within the limits of this group. Wheat has occupied approximately its present position in the agriculture of this region for more than a century, a sufficient length of time for the farmers to have found the most profitable acreage of it. Yet the facts have not been definitely recognized by these farmers. Many of them grow either more or less wheat than these results indicate they should.

The figures for percentage of income from wheat are in close agreement with the above, and confirm the conclusion that on the major portion of these farms this crop occupies its proper position, as is seen in Table XIII.

TABLE XIII.—*Relation of percentage of income from wheat to labor income.*

Per cent of income from wheat.....	None.	1 to 9.	10 to 19.	20+.
Number of farms.....	36	204	121	17
Adjusted labor income.....	79	121	82	19

Average percentage of wheat area on the 378 farms, 18.2.

Thirty-six farms sold no wheat. Their labor incomes average much lower than the general average. Two hundred and four farms derive from 1 to 9 per cent of their income from the sale of wheat. Their profits are much above the average. One hundred and twenty-one farms received from 10 to 19 per cent of their income from this source and made profits much below the average. The number of farms deriving more than 20 per cent of their income from wheat is small. This fact is in itself significant. While their number is too small to give a very significant average, the fact that this average is exceedingly low is consistent with the other data of this table and

those of Table XII. These figures indicate that while the place wheat should occupy on these farms is one of moderate importance, it is distinctly more profitable to grow a field of wheat in the rotation than not to do so under the conditions prevailing in this region.

The high prices for wheat which have prevailed during the latter part of 1914 and the early months of the present year (1915) would undoubtedly justify a larger percentage of wheat acreage than that here indicated, but these conditions are abnormal. The price of wheat will undoubtedly fall again to about its previous normal level when the present disturbed conditions have passed. It would, therefore, probably be wise for the farmers of Chester County to continue their present practice with reference to this crop.

Oats.—The oat crop occupied 6.4 per cent of the crop area on these farms in 1911. It was found on 238 of the 378 owner farms. In only six cases did it exceed 20 per cent. This crop occupies a portion of the second year in the common rotation, along with potatoes and some of the corn. That it would pay better to omit oats entirely from the cropping system is clearly indicated in Table XIV, where it is seen that the 140 farmers growing no oats made profits 17 per cent above the average, the 141 farmers having from 1 to 9 per cent of oat acreage made profits 2 per cent above the average, while the 97 farmers having 10 per cent or more of their crop area devoted to this crop made profits 27 per cent below the average.

TABLE XIV.—*Percentage of crop area in oats as related to labor income.*

Per cent of crop area in oats.....	None.	1 to 9.	10.
Number of farms.....	140	141	97
Adjusted labor income.....	117	102	73

Average percentage of crop area in oats, 6.4.

Attention is elsewhere called to the fact that an annual hay crop might profitably replace oats in the common rotation system prevailing here. The quantity of oats sold by the farmers of this locality is too small to permit any conclusions being drawn concerning the relative profitableness of feeding or selling this product.

Hay.—Timothy and clover hay occupy 44 per cent of the crop land on the farms here under consideration. Only two farms had none of this crop. Few farms have less than 30 and few more than about 55 per cent of their crop land in hay. The total area of other kinds of hay is so small that it may be neglected without serious error. The data given in Table XV show that the largest number of farms have from 40 to 49 per cent of hay acreage, and that these farmers make higher profits than those having a greater or a smaller acreage.

TABLE XV.—*Percentage of crop area in hay as related to labor income.*

Per cent of crop area in hay.....	0 to 29.	30 to 39.	40 to 49.	50 to 59.	60+.
Number of farms.....	33	107	145	74	19
Adjusted labor income.....	96	93	107	105	72

Average percentage of crop area in hay, 44.

Thus the larger number of farmers, as well as the average of all the farms, falls within the limits of the most profitable acreage. In other words, the farmers here have in a general way, and perhaps without any very definite knowledge that they were right, responded to the economic pressure which tends to drive them in the direction of the greatest profit. The hay crop ordinarily occupies the land for two years in a five-year rotation, but a sufficient number of the farmers leave their hay lands down for a year longer, and occasionally even longer than this, to bring the percentage area of the crop somewhat above the 40 per cent line. It is probable that the substitution of soy beans for oats in the second year of the rotation would obviate the necessity of leaving meadows down for more than two years except for pasture, unless the soys are grown for seed.

We have already seen in Table VIII that hay is the second most important direct source of cash income in this region. While it occupies twice the area of any other crop, a large proportion of the crop is fed. Here again the question arises whether it would pay best to feed all the hay, sell all of it, or feed part and sell part. If the latter, then what proportion of the farm income may legitimately be derived from the sale of hay? Fortunately, the data on this point are such as to give quite a definite answer to the query. During the year to which these records relate 298 of the 378 farms operated by their owners sold some hay. The highest proportion of income from this source on any farm was 57 per cent. The percentages for the different farms are fairly evenly distributed between 1 and about 25 per cent, gradually falling off beyond this point. Table XVI shows quite conclusively that those farmers who derive from 1 to 9 per cent of their income from the sale of hay make higher profits than any others, and that, next to these, those who derive from 10 to 19 per cent make the most profit.

TABLE XVI.—*Relation of labor income to percentage of income from hay.*

Per cent of income from hay.....	None.	1 to 9.	10 to 19.	20 to 29.	30+.
Number of farms.....	80	78	114	64	42
Adjusted labor income.....	78	132	112	98	55

It is clearly indicated here that under the conditions prevailing during the year of the survey the most profitable practice is to grow a little more hay than is needed for feed on the farm. It will be noticed, however, that the number of farmers in the second most profitable group is somewhat larger than in any other. The price of hay, due to a shortage in yield, was rather high during 1911, the average sale price being \$22.12. These high prices probably induced a larger number of farmers to sell hay than is ordinarily the case.

Fruit.—Of the 378 farms here under consideration, 315 reported some fruit acreage, the average percentage area being 2.5. On only 10 farms did this acreage exceed 10 per cent. In by far the larger number of cases it was less than 5. Fruit is thus very generally grown, but almost entirely for home use. Commercial fruit growing does not appear to be adapted to the conditions prevailing in this locality. Just why this is the case has not been determined, but it is probable that the character of the soil is the main factor. The topography is also less broken than it is in most of the leading orchard districts, thus giving rather poor air drainage and exposing the early blooming varieties of fruit to danger from untimely spring frosts.

The relation of fruit acreage to labor income is shown in Table XVII. The 63 farmers who reported no fruit trees on their farms made labor incomes 9 per cent below the general average.

TABLE XVII.—*Acres in fruit as related to labor incomes.*

Acres in fruit.....	None.	1 to 5.	Over 5.
Number of farms.....	63	306	9
Adjusted labor incomes.....	91	103	48

Those having 1 to 5 acres of fruit made labor incomes 5 per cent above the average, while the 9 farms having a larger acreage made less than half the average labor income.

While fruit occupied an average of 1.35 acres, or 2.5 per cent of the crop area on each of these farms, the income from the sale of fruit was only seven-tenths of 1 per cent of the total receipts, as shown in Table VIII. In most cases the receipts are only 1 or 2 per cent of the total farm receipts. In only five cases did the percentage exceed 10, the maximum being 28 per cent.

The relation of income from fruit and labor income is shown in Table XVIII. A majority of the farms sold no fruit, but their labor incomes were below the average. A large number derived from 1 to 9 per cent of their income from this source, and made labor incomes 13 per cent above the average.

TABLE XVIII.—*Percentage of income from fruit as related to labor income.*

Per cent of income from fruit.....	None.	1 to 9.	10 to 19.	20+.
Number of farms.....	261	112	3	2
Adjusted labor income.....	95	113	85	88

The numbers in the higher groups are too small to be significant, but in both groups the results are considerably below the average. It is quite probable that if cost accounts were kept with these orchards they would appear to be unprofitable. But the small acreage requires little care, and the time devoted to them is seldom taken from more profitable endeavor. At any rate, the figures, both as to acreage and as to proportion of income, show clearly that on those farms on which fruit constitutes one of the minor enterprises the profits are greater than where it is entirely absent. At the same time they indicate that the proper position of this crop is that of a decidedly minor enterprise. We have here what appears to be a good illustration of the principle that within certain limits it pays well to produce home supplies and to conduct a properly diversified business.

Truck crops.—As previously stated, kitchen gardens were not taken into account in this survey. Other studies, however, have shown that the farmers of this general region almost universally grow a liberal supply of vegetables for home use. Situated as this area is, not far from several large cities, it would naturally be expected to find considerable development of commercial truck growing here. But such is not the case. Only 23 of the 378 farms derived any income from this source. This general region is one in which commercial truck farming is perhaps as highly developed as it is anywhere in this country, but the amount of vegetables grown is so vast that the supply is practically always greater than the demand, except during the early part of the season for each of the various truck crop products. It is therefore only those who can reach the market early who find the business profitable, and to do this requires a light sandy soil that warms up rapidly in the spring and thus conduces to earliness. The soils of this area are in the main heavy, and hence truck crops mature late in the season. Here and there, however, is a farm with more or less warm sandy land, and a few of these are devoted more or less to this type of farming. Some of them deliver their product by wagon to Wilmington, Del., a distance of 15 miles from the center of the survey area. Of the farms conducting a trucking business, only two have more than 20 per cent of their acreage devoted to it.

Twenty-three farms derived a portion of their income from the sale of vegetables. Three of them sold a small quantity of such

products from their kitchen gardens and reported no acreage of commercial truck crops. In the case of both acreage and income the number of farms is too small to permit a satisfactory comparison between labor income and magnitude of the trucking business, such as has been made above for other crops. The small number of these farms is itself an indication that the business is not at home here, even if the population to be supplied is very large.

Poultry.—The receipts from poultry and eggs constitute 8.2 per cent of the total receipts of the 378 farms. Only eight of the total number reported no income from this source. From the standpoint of the number of farms, this enterprise, therefore, heads the list of farm enterprises in this locality; that is, it is the most universally found of any farm enterprise. But we have already seen that in very few cases do the flocks exceed 200 hens. Poultry thus constitute one of the more important of the minor enterprises on the farms of this region, as they do so generally in nearly all parts of this country. Do these poultry pay? They furnish a very important part of the family living, but this is not taken into account in this study. The data here given relate only to the commercial phase of the business. If they are profitable, why do not farmers keep larger flocks? These questions are quite definitely answered in the data obtained in this survey, and the answer is one of great importance both to the farmer whose poultry are merely incidental to the general farm business and to the poultryman who makes of them a major enterprise.

Percentages of income from poultry are about equally numerous from 1 per cent up to about 9 per cent. Above this the numbers fall off rapidly. Fifty-one farms derive more than 20 per cent of their income from this source and eight farms more than 40 per cent. Thus, of 370 farms keeping poultry, only 8 would be classed as real poultry farms, while of 347 farms deriving incomes from the sale of dairy products, 157 are classed as real dairy farms, and that, too, without counting income from the sale of cows and calves. Why is the more universal poultry enterprise in nearly all cases a minor one while the somewhat less common dairy enterprise is so frequently the leading source of income? The figures given in Tables XIX and XX show the reason for this to be that when the poultry business is made a minor enterprise it is profitable, while when it rises to the dignity of a major enterprise it often becomes unprofitable or at least much less profitable than when it occupies a minor place on the farm. On the other hand, the dairy business in this region is more profitable as a major than as a minor enterprise.

Unfortunately, the number of farms in two of the classes of Table XIX is quite small, but the very low average labor income in both these classes can hardly be regarded as insignificant.

TABLE XIX.—Percentage of income from poultry as related to labor income.

Per cent of income from poultry.....	None.	1 to 9.	20 to 39.	40+.
Number of farms.....	8	319	43	8
Adjusted labor income.....	38	104	97	40

The numbers in the remaining classes are quite sufficient to give averages having a definite meaning. Farmers deriving from 1 to 19 per cent of their income from poultry make profits above the average, while those deriving more than 20 per cent of their income from this source make profits below the average. Furthermore, the largest number of farmers are in the class making the greatest profits. In other words, the farmers of this region have been driven by economic forces, which are not always definitely recognized, to give the poultry enterprise the position on their farms which conduces to the greatest profit. The fact that the forces acting in this case are not universally recognized and understood is proven by the fact that quite a number of farmers have not responded to them.

We shall perhaps find no better illustration than this of the fact that it would not always pay the farmer to do cost accounting, and as a result of the information thus obtained increase the magnitude of his most profitable enterprises and eliminate those which the bookkeeping records indicate to be unprofitable. The Office of Farm Management has kept books on farm poultry under conditions similar to those prevailing on the average farm of this region, and when the time and material devoted to them are charged at current rates the results showed a loss for the year. Doubtless the same would be true on most of these farms. Yet the data given show that they are profitable when kept within proper limits. It is, of course, possible to make a real poultry farm profitable, especially near a good market, and such farms are to be found. But it is difficult to do so. The poultryman finds himself in competition with farm flocks that are kept at nominal expense, both the time and materials consumed in their management being otherwise largely unutilized. The business may thus be distinctly profitable to the farmer with a small flock, while the poultryman under the same conditions would find it much more difficult to make a profit. One or two of the real poultry farmers found in this survey made fair profits, but they were unusual men.

Dairying.—It has been made clear in the foregoing discussion that this is preeminently a dairy region. The receipts from dairy cattle and their products together constitute 44 per cent of the entire income of these 378 farms. It will later be seen that on the tenant farms dairying is even more important than it is on those operated by their owners. For the past third of a century the production of

market milk has been the standard type of dairy farming in Chester County. It is by far the most important enterprise found in this survey. The number of farms deriving various percentages of income from dairy products is fairly evenly distributed from about 20 per cent to about 60 per cent of income from this source. Above and below this the farms are less numerous.

The income from cattle is in the main a mere incident to the selling of dairy products, and represents usually the selling of a few calves and discarded cows. There are only nine of these farms which derive more than 20 per cent of their income from the sale of dairy cattle. Six of these are farms on which the income was so small that the few dollars received from the sale of a few calves and a cow or two was the principal income. But the other three are farms which make a business of raising well-bred stock for sale for breeding purposes. These three farms made very good profits. It would appear that there is room here for a much greater development of the pure-bred stock business. In a region so distinctly devoted to a type of live-stock farming as this is, there should be good business for more than 3 out of 378 farms devoted to producing high-class breeding stock for their neighbors. Perhaps the fact that until recently it has been possible here to buy fairly good cows more cheaply than they could be raised in a region of high-priced market milk is largely responsible for the very general absence of the breeding business. More recently the price of cows has advanced. During the year of this survey (1911) the average price paid for cows was \$63.84. At this price farmers can afford to raise them even with the high local prices of milk and feed. Since the survey records were taken there has been an increase in the percentage of calves saved.

In order to keep up a herd of dairy cows, both in numbers and in quality, it is necessary to replace an average of about 25 per cent of them annually. Of these 378 farms an average of 23 per cent were actually replaced, 8.2 per cent by cows raised on the farm, the remainder by purchase. Thus, about one-third of the cows necessary to maintain the herds are raised. It is to be presumed that as the proportion of cows raised increases, which seems likely to be the case with the high prices now prevailing, the number of pure-bred herds will increase in number. Partly because of the general dependence on purchased cows, there is less uniformity of breeds on individual farms in this region than might be expected where more of the cows are raised.

It has been shown in the foregoing pages that in the case of most of the enterprises found on these farms there appears to be a particular status which each enterprise should occupy for best results.

When one of these enterprises is given a magnitude greater or smaller than this the farm profits become less. This does not appear to be the case with the dairy enterprise on the average farm. Table XX shows that the average labor income of each group of farms deriving 20 per cent to 90 per cent of their income from dairy products is above the general average of the community.

TABLE XX.—*Percentage of income from dairy products as related to labor income.*

Per cent of income from dairy products.....	None.	{1 to 9.	10 to 19.	20 to 29.	30 to 39.	40 to 49.	50 to 59.	60 to 69.	70 to 79.	80 to 89.	}90+
Number of farms.....	31	26	26	65	73	71	47	19	11	7	2
Adjusted labor income.....	43	94	82	114	103	109	102	130	103	101	55

It is considerably lower on those farms deriving less than 20 per cent of their income from this source. These figures indicate that under the conditions prevailing in this region the dairy business may be made profitable whatever position it may occupy on the farm, provided, of course, the cows be of good quality. This is the only enterprise in this region of which this is true.

It is to be inferred from these results that if the cows are of high quality it is relatively unimportant whether the farmer has several other more or less important sources of income. With cows of poor or ordinary quality it becomes increasingly important that the business be diversified; that is, that other sources of income be provided. This conclusion is strongly reinforced by the results given in Table XLIV, in which it is shown that with cows producing less than \$50 worth of product annually the larger the herd the less the profit, while with cows producing more than \$100 worth of product the larger the herd the greater the profit.

The failure of Table XX to show a particular percentage of income from dairy products to be more profitable than any other may be due to the fact that the quality of the cows on the various farms is highly variable, and, as will be shown later, the producing capacity of the cows is one of the very most important factors of profit on these farms. If the labor income could be further adjusted so as to eliminate the effect of variation in quality of cows, it might be found that there is an optimum status of the dairy industry here. It is also practically certain that if all the cows were as good as the best the most profitable percentage of income from this source would be higher than if the cows were all of poor or medium quality.

Types of dairying.—Table XXI shows the relative importance of the various types of dairying in the Chester County survey area. The farms here represented as selling creamery milk differ from those

selling market milk only in the fact that during the summer time, when there is a superabundance of market milk, these farms sell to local creameries.

TABLE XXI.—*Relative importance of different types of dairying, Chester County owners.*

Types.	Number of farms selling only one dairy product.	Total number of farms selling. ^a
Butter making ^b	54	62
Creamery and market milk.....	204	209
Market milk.....	74	77
Condensary milk.....	6	6
Nursery.....	1	1
Buttermilk.....		1
Total.....	339	356

^a There are 8 farms selling more than one form of dairy product; 4, butter and creamery milk; 2, butter and market milk; 1, butter, creamery milk, and market milk; 1, butter, skim milk and buttermilk.

^b Butter making is confined principally to farms having too small a quantity of milk to justify delivery at a creamery or shipping station. (See Table XXII.)

Practically all of those farms here listed as "creamery and market milk" farms are really market-milk farms doing business for a portion of the summer season with the creameries. In all there are 209 farms following this practice, while 77 produce market milk, but do not patronize the creameries. There are 62 farms that make some butter, and 54 of these sell no other dairy product. Six farms sell all their milk to a condensary, one makes a specialty of nursery milk for children, and one sells some buttermilk. There is some duplication of farms in the last column of Table XXI. Several of these farms sell more than one kind of dairy products. This duplication is eliminated in the preceding column, which shows the number of farms selling only the one kind of product mentioned.

As previously stated, butter making was formerly an important feature of the dairy business in this locality, and continued as such until the development of the market-milk business, which began about 45 years ago. At the present time butter making on the farm occupies a very subordinate position. It is confined almost wholly to those farms having only a few cows, and hence not enough milk to justify daily delivery at a shipping point. There are also a few farms having a special trade in fancy butter. Table XXII shows that of those farms having 6 cows or less, 38 per cent sell some butter. Of those having more than 6 and not more than 18 cows, only about 6 or 7 per cent sell any butter. Those with more than 18 cows sell no butter.

TABLE XXII.—*Relation of number of cows to butter making.*

Number of cows.	Number of farms.	Per cent of farms selling butter.	Per cent of farms selling dairy products in other forms.	Per cent of farms selling no dairy products.
6 and less.....	123	38.2	39	22.8
6.1 to 12.....	122	5.7	92.6	1.7
12.1 to 18.....	71	7.0	91.6	1.4
18.1 to 24.....	39		100	
Over 24.....	23		100	

Table XXIII indicates that those farmers who sell milk during the summer season to creameries make more profit than those who ship to wholesale milkmen the year round. Thus, of the 60 farms 61 to 80 acres in size, 65 per cent sell some milk to creameries in the summer time, while 18.3 per cent ship market milk the year round. The labor income of those who sell milk to the creameries averages \$804, while that of the exclusive market milkmen is only \$612, or about 24 per cent less than that of the men who sell some creamery milk.

TABLE XXIII.—*Relative profitableness of creamery milk and market milk in Chester County.*

Size groups.....acres..	61 to 80.	121 to 160.
Number of farms.....	60	61
Per cent selling creamery milk.....	65.0	65.6
Per cent selling market milk.....	18.3	18.2
Labor income of those selling creamery milk.....	\$804	\$1,267
Labor income of those selling market milk.....	\$612	\$1,010
Difference.....	\$192	\$257
Per cent of larger income.....	23.8	20.3

A very similar result is shown for the 61 farms in the 121 to 160 acre group. The same proportion of men sell part of their milk to creameries, the same proportion sell only market milk, and the labor income of the latter is 20 per cent less than that of the former.

There are probably two reasons for this difference in the profits made by these two groups of men. In the first place, those who are so situated as to be able to patronize the creameries get approximately as much for their cream as they would for whole milk, and have their skim milk left as feed for calves, poultry, and pigs. In the second place, it is probable that those who sell creamery milk do more summer dairying than those who sell only market milk, and on account of the very excellent pastures in this locality their cost of production averages lower than it does on farms that do more winter dairying.

Beef cattle.—A few farms were found in this survey on which a number of cows of no particular breed, but mostly of dairy blood, were kept but not milked. They were utilized to raise a number of

veal calves. The owners called these beef cattle. These farms were operated by men who had no help. The labor incomes on all of them were very unsatisfactory.

Twenty-seven farms were found on which steers were fed. The percentage of receipts from steers on each of the 27 farms exceeds 20 on only 10 farms and 40 on 2 farms. Steer feeding is thus a business little followed in this section. This of itself is an indication that conditions are not generally favorable to the steer-feeding business, especially when it is remembered that in the early days this was a leading industry in Chester County. Its absence is not merely due to lack of knowledge of the business, but to lack of economic conditions favoring it. We have also seen that in the main this business tends to gravitate to the larger farms. It appears especially on those farms that are somewhat too large for one-man dairy farms, and again more commonly on farms too large for two-man dairy farms. It is an extensive system of farming. Ordinarily the profits from it are so small that the small farmer can not well make a living at it. It appears, however, to be a fairly satisfactory business on large farms in this area.

The relation between steer feeding and the resulting labor incomes is shown in Table XXIV:

TABLE XXIV.—*Percentage of income from steers as related to labor income.*

Per cent of income from steers.....	None.	1 to 19.	20+.
Number of farms.....	351	17	10
Adjusted labor income.....	101	94	86

Three hundred and fifty-one of the farms fed no steers and made profits slightly greater than the average. The 17 farms deriving from 1 to 19 per cent of their income from steers made labor incomes 6 per cent below the average. The 10 farms deriving a larger share of income from this source made labor incomes 14 per cent below the average. These results, though based on rather meager data, are consistent with those found in other surveys where small farms are the rule.

Sheep.—As previously stated, sheep were found on only 14 of these farms. Six of them had flocks of breeding ewes numbering from 35 to 55 head. The others had only a few head each. The numbers are too small to give very significant results in a comparison of labor incomes on farms with and without sheep, but this fact of itself indicates that these animals are poorly adapted to the conditions prevailing here. The 364 farms having no sheep made labor incomes 1 per cent above the average. Twelve farms deriving 1 to 19 per cent of their income from sheep made labor incomes 26 per cent below, and

the 2 farms deriving a greater portion of income from them made labor incomes 39 per cent below the average. As has already been stated, sheep represent a form of extensive farming which, in this region as elsewhere, tends to gravitate toward the larger farms.

In regions where the farms are not heavily stocked with animals that are capable of consuming the coarse roughage and the natural growth that would go to waste on various parts of the farm, it would probably pay to keep a small flock of sheep as scavengers. So long as their feed consists largely of such materials they should be profitable. Small numbers of sheep may be moved about the farm in such a way as to avoid largely the danger of infection from parasites. When large numbers are kept the battle against parasites becomes a severe one. Generally speaking, the eastern farmer can not compete with the western ranges and those of the Appalachian Mountain country in raising sheep. The winter feeding of lambs is a different business. No examples of it were found in this area. It is too far removed from the source of supply of feeders. Most of the farms are also too small to make this business satisfactory. The profits are too small for the small farmer.

Swine.—In the days before the development of the dairy industry here, and during the early history of dairying, when butter making was its prominent feature, swine occupied an important position in the agriculture of Chester County. The Chester White breed of swine originated here and took its name from that of the county. Since the decline of butter making swine have assumed a minor place in the local agriculture, though they are quite generally kept in small numbers as a means of producing home supplies. About half the farms analyzed in this survey sold a small quantity of pork products. Five of them derived from 20 to 30 per cent of their income from this source and 24 others from 10 to 20 per cent. On the face of the returns those farms deriving part of their income from swine made greater profits than those that did not, but the data are not sufficiently extensive to demonstrate that hogs are more profitable here than the local farmers generally consider them to be. So far as they go, the indications are that it would pay these farmers to give more attention to swine.

Most profitable combination of enterprises.—From the foregoing discussion it appears that dairying may occupy almost any status in this region from that of furnishing about one-fourth of the income to that of almost the sole source of income, the latter especially if the cows are of high quality and the farm is well stocked with them.

Of the remaining enterprises, the most profitable status appears to be approximately as follows: Corn should occupy all the first year and a good part, if not all, of the second year of the rotation,

and most of the crop should be fed. Oats should be entirely eliminated, and their place should be taken by an annual hay crop. This crop may occupy a part of the second year of the rotation with corn and potatoes, or if corn occupies all of the first and second years, it may occupy the third year, along with the potatoes. The proper position of the potato crop is not revealed in these studies, for the reason that the price was abnormally high the year the data were taken. It is probable that the status they now occupy is approximately what it should be. Especially on the smaller farms they help to fill the labor schedule. Wheat should occupy one year in the rotation and hay two years. Most of the hay should be fed, but especially on the larger farms a good deal of it may be sold with profit. Fruit should be grown as a means of producing home supplies, and a small amount may be grown for sale. Beyond this it does not seem advisable to go into the matter of fruit culture.

Apparently the farmer of this locality should give somewhat more attention to swine, especially as a means of producing home supplies, but also as a minor source of income. Each farm should keep a flock of hens, usually not less than 50, nor more than 150 or 200. The exceptional man, especially if his farm is small, may give this enterprise more attention than this. Steer feeding should, in the main, be confined to farms that are not adapted to the dairy business, usually for lack of suitable labor, and should ordinarily be confined to farms of considerable size. The same is true of sheep. They do not appear to be so well adapted to the conditions prevailing here as steers. It is only the large farmer who can hope to make a satisfactory profit from them in this region.

The farmer who has a large herd of exceptionally good cows can afford to give less attention to other sources of income. But as the quality of the cows decreases their number should also decrease, and the farmer should depend more and more on other sources of income. Thus he might sell more hay and corn, keep a few more hens, give more attention to hogs, etc.

The importance of the dairy cow in this region renders it highly important that the farmers give more attention to improvement in the quality of their cows. This can hardly be done so long as the major portion of the cows are bought, for cows of the best quality are usually not for sale, and even when they are the price is so high that the farmer will find it more profitable to raise them. This subject is further discussed in connection with quality of the farm business later in this bulletin.

Résumé of conditions affecting types of farming.—In the preceding pages we have found that on by far the greater number of farms in this region dairying is the major enterprise, with hay, wheat, and

poultry of considerable importance, while potatoes, hogs, and corn constitute considerable, though less important, sources of direct income. Fruit is the only other enterprise generally found on these farms, and in nearly all cases it is a very small enterprise, designed principally for the production of home supplies. We have also found that the sources of income on these Chester County farms differ radically from those in certain other sections of the country. While some of these differences may be due merely to local customs inherited from the preceding generation of farmers, there are also deeper underlying causes.

The principal factors which determine the distribution of farm enterprises are climate, soil, and local conditions with reference to market demands, market prices, and the character and amount of the available supply of labor. These are the factors which, in general, determine whether or not a given enterprise is adapted to a specific locality, but it does not at all follow that because an enterprise is adapted to the conditions prevailing generally in a region it is adapted to every farm in that region, for the business conditions on individual farms may make neighboring farms adapted to quite different types of farming. We have already seen that some of the types of farming found in Chester County can be made quite successful if the farm is large enough. This is especially true of steer feeding. In some localities the distance to a shipping point may have considerable effect on the types of enterprises which each individual farmer should select. The amount of labor available to the farmer, the amount of capital at his disposal, and the character and amount of the equipment already on the farm also have an important influence in determining the enterprises which the individual farmer should attempt to maintain. Unless, therefore, the conditions which determine what enterprises are adapted to the region as a whole limit the profitable enterprises to a very small number, we should expect to find considerable diversity in types of farming. In Chester County the enterprises adapted to the general region are comparatively few in number, though more numerous than is the case in some other sections of this country. It happens also that the one enterprise which seems best at home here, namely, dairying, can be successfully conducted, if right methods are used, on farms varying greatly in size. For these reasons we find greater uniformity in the type of farming in this locality than is generally the case in most parts of the country. There is considerable diversity in the local agriculture, but it is a diversity which is characteristic of the individual farm and does not in general result in classes of farms devoted to different types of farming.

Table XXV gives the list of enterprises which are of any importance in this region, together with the factors which are favorable and

those which are unfavorable to each. This table is almost self-explanatory. It will be noted that dairying is handicapped by but one unfavorable condition and that one which can be neutralized by breeding up the dairy herds to meet the high price of hay and grain with a maximum milk production.

TABLE XXV.—*Some favorable and unfavorable conditions affecting types of farming, Chester County.*

Enterprises.	Favorable conditions.	Unfavorable conditions.
Dairy.....	Good markets; excellent pastures; corn; hay; size of farms; character of labor; gives winter employment.	High price of hay and grain.
Hay.....	High prices; usefulness as feed; soil; climate.	Short season of employment.
Potatoes.....	Nearness to markets; climate favorable; distributes labor.	Prices variable; low yields; soil.
Wheat.....	Soil; nurse crop for grasses; seasonal distribution of labor; furnishes bedding.	Small farms; western competition; small profit per acre.
Poultry.....	Excellent markets; soil; climate; production of home supplies; utilization of spare time and waste materials.	Competition from small flocks everywhere.
Hothouse products.	Nearby great city; provide winter work.	Diseases; danger of overproduction.
Hogs.....	Good market; pastures.....	High price of concentrates; danger from cholera; competition with dairying; lack of skim milk.
Corn.....	Good market; usefulness as feed; soil; climate.	Furnishes no profitable employment from July to late September.
Truck crops.....	Good market; home supplies.....	Competition of near-by soils better adapted.
Fruit.....	do.....	Soil (?); topography (?); fluctuation of production and prices.
Beef cattle.....	Good market; crops; pastures; climate.	High price of feed; smallness of farms; competition with dairying.
Sheep.....	do.....	High price of feed; smallness of farms; parasites; dogs; competition with dairying; small per cent of nonarable land.
Oats.....	Value as feed.....	Climate; small value per acre; poor nurse crop.

Relation of type of farming to distance to market.—The region of this survey is so well provided with transportation facilities that none of the farms is located more than 5 miles from a possible shipping point. A tabulation of the various types of farming and their relative frequency at different distances from shipping points shows practically no relations existing in this territory between the two. There are localities, however, in which many farms are located at great distances from a shipping point, and in which this fact becomes an important factor in determining the enterprise best suited to individual farms.

Special farms.—As previously stated, 27 of the owner farms found in this survey were either wholly or partly devoted to the production of hothouse products, mainly mushrooms. A few farms produced hothouse tomatoes, and two of them derived a large per cent of their income from carnations. For the year of this survey (1911) these special farms made very satisfactory profits, considerably larger than farms of other types in this region, but it would be ruinous from the standpoint of profits for the farmers of this region generally to undertake a hothouse business. Overproduction would be inevitable.

The data obtained about the details of the hothouse business in this locality were not sufficient to permit a more detailed consideration of these special farms in this bulletin.

MAGNITUDE OF THE FARM BUSINESS.

The magnitude of the farm business may be measured in a number of ways. In comparing farms where the land is of similar character and of the same price per acre, the magnitude of the farm business is quite closely proportional to the sum of the interest on the capital invested, current expenses, depreciation, and wages for the operator. But this method would not be accurate in dealing with farms on which the land differs widely in price but not in yielding power. If the land is very high priced, a given amount of business might require a very large amount of capital, while with low-priced land the same amount of business will require much less capital.

In most farm-management surveys the land of the different farms included is at least comparable in price, or where this is not the case the differences in many cases are due to difference in the real value of the land for farm purposes. Under such conditions it is fairly easy to establish a basis on which to measure the magnitude of the farm business. The problem is much more difficult when a comparison is to be made between farms in different regions in which the economic conditions, especially land prices, are widely different.

In dealing with the farms of a limited region where the various types of farming do not differ markedly in the amount of labor required in comparison with other expenses, perhaps the most accurate measure of magnitude is the sum of the area in crops and the crop area equivalent of the area in pasture. But it is not always easy to determine how many acres of pasture are equivalent to one acre of field crops from the standpoint of feed produced. If the comparison to be made, however, includes farms on which the percentage of pasture land varies widely, it is necessary to use some such basis as that just mentioned in order to get a fair comparison of magnitude.

In the area here under consideration the proportion of land in pasture, especially when the farms are considered in groups, varies within narrow limits. In such cases the area in crops alone gives a fairly satisfactory measure of magnitude, since it is proportional to the sum of the crop and pasture area.

In many localities a considerable proportion of every farm is made up of rough land, frequently occupied by timber, and in such regions the proportion of the farm thus occupied may vary greatly. In such a case it is evident that the size of the farm—that is, the number of acres in the whole farm—is utterly useless as a measure

of the size of the farm business. In these cases it would be better to use the crop area plus the crop equivalent of the pasture area. By referring to Table II it will be seen that when the farms in this survey are averaged in groups the total woodland and waste land varies within narrow limits. Hence in this Chester County area the size of the farm itself is very closely proportional to the magnitude of the farm business. For this reason it has been used in this bulletin in the tabulations which involve the relation of the magnitude of the farm business to other factors. This method, as above stated, would not be applicable to a region in which a large and variable proportion of the land is practically unused in the business.

THE MINIMUM EFFICIENT UNIT.

The "minimum efficient unit" in agriculture is a farm of sufficient size and so organized as to give full employment at productive labor to the farm family. The farm may be any amount larger than this, provided the operator has sufficient managerial ability to make the larger business efficient, but there are very distinct disadvantages if the farm business is smaller than the most efficient unit as above described. When such is the case the farm family does not have the opportunity to exert its full earning power.

The fact that the minimum efficient unit in farming is relatively very small as compared with most other industries is the most attractive feature of farming as a business. Because of the small size of this unit economic independence is fairly easy of accomplishment, and many prefer independence with a moderate competence to dependence with a very small chance of pronounced success.

The ideal size of farm is somewhat larger than the minimum efficient unit. It is such as to permit a high standard of living and the education of the farm children, but the ordinary family farm with good management will often permit this.

Farms in the North Atlantic States are mostly small in area. The reason for this is mainly historical and has already been set forth in the introduction to this bulletin. Attention has also been called to the fact that in increasing the farm business on these small farms in order to meet the competition with larger farms in the West, the line of least resistance was represented by the development of more intensive farming rather than extension of acreage, though examples of both methods of enlarging the business are frequently found. It requires somewhat greater ability on the part of the farmer to conduct an intensive business on a small area than it does a more extensive business of similar magnitude on a larger area. Hence, a large proportion of eastern farmers with small areas of land at their disposal have not been as successful as might be wished in developing

a business of suitable magnitude. There are still very many eastern farms that are far too small for satisfactory results. In this survey, of the 378 farms conducted by their owners 54 of them were from 13 to 40 acres in area. The average labor income made by these 54 farmers was only \$240, which is considerably less than ordinary farm wages. (See Table XXVI.)

Just the opposite condition is found in the corn belt. There magnitude of business is obtained by extent of acreage, and large farms are the rule, small ones being the exception. Since there is ample demand for the principal products of intensive farming in the region of Chester County, it is perhaps fortunate that the average size of farm is such as to require at least a considerable degree of intensity in the farming. The relatively small farm makes it possible to maintain better schools and a more satisfactory social life in the country, but this applies only to farms of moderate size in this area. A large number of farms are too small to permit satisfactory profits to the owners.

RELATION OF SIZE OF FARM TO LABOR INCOME.

The relation of size of farm to labor income is shown in Table XXVI. The farms 13 to 40 acres in size, averaging 28 acres, are 54 in number, with an average labor income of \$240 per year. This represents what the farmer himself gets for his labor and managerial ability, the value of the unpaid family labor having already been accounted for as a part of the expenses of the business.

TABLE XXVI.—*Relation of size of farm to labor income on 378 farms operated by owners in Chester County.*

Size of farms, in acres.	Number of farms.	Average size.	Average labor income.	Per cent of farms with labor income \$1,000 or more.
		<i>Acres.</i>		
13 to 40.....	54	28	\$240	6
41 to 60.....	61	52	550	10
61 to 80.....	60	73	730	25
81 to 100.....	68	93	848	34
101 to 120.....	52	110	937	46
121 to 160.....	61	136	1,034	46
161 to 393.....	22	203	1,575	68
Average.....	378	90	789	30

A good many of these farmers found it necessary to obtain a considerable proportion of their income from work outside the farm. In addition to this, the farm family has what the farm furnishes toward the family living, and interest on the capital invested. Only three of the 54, or about 6 per cent of the whole, made labor incomes in excess of \$1,000. The next group of farms, consisting of those

from 41 to 60 acres in area, and averaging 52 acres, contains 61 farms. The labor income was, on the average, \$550. Ten per cent of these farmers had labor incomes over \$1,000. There were 60 farms of 61 to 80 acres in area, averaging 73 acres, and having an average labor income of \$730. Twenty-five per cent of this group made labor incomes over \$1,000. In the 81 to 100 acre groups 68 farms, averaging 93 acres in area, produced an average labor income of \$848, 34 per cent of them being over \$1,000. Of the 52 farms in the 101 to 120 acre group, averaging 110 acres, the owners made an average labor income of \$937, 46 per cent of them being above \$1,000. Above this acreage the number of farms falls off rapidly, and in order to secure a number of farms comparable with those in the preceding groups it was necessary to broaden the size limits of the group to 40 acres. This gives 61 farms of 121 to 160 acres, averaging 136. The average labor income was \$1,094. Here, again, 46 per cent of the farmers earned over \$1,000 each. There were only 22 farms of more than 160 acres, the largest being 393 acres. The average area of the 22 farms is 203 acres and the average labor income of the owners \$1,575. Sixty-eight per cent of these large-farm owners made labor incomes in excess of \$1,000. We have here a very conclusive demonstration of one of the fundamental principles of farm management, and that is that one of the most important factors of efficiency in farming is the magnitude of the farm business.

The prevalent style of farm organization in this region is such that the magnitude of the business conducted on a given area is considerably larger than on a similar area in most sections of the Middle West, so that the labor incomes obtained here on farms, say of 40 to 80 acres, are comparable with those obtained on considerably larger farms in regions where the farming is less intensive. While only 10 per cent of the farmers of the 41 to 60 acre group made more than \$1,000 labor income, the average of this group was \$550, which is fairly satisfactory when it is remembered that in addition to this labor income the family has the interest on its investment and whatever the farm furnishes toward the family living. Such an income will permit a very satisfactory standard of living, but it must be remembered that it is more difficult to make a good living on a farm of this size even in this region than it is on a larger farm, and when we come to consider tenant farming here we shall see that tenants, as a rule, avoid the small farms. *Below 40 acres the difficulties of success with the type of farming most prevalent in this region, namely, dairying, are so great that only one man in sixteen was able to make over \$1,000 a year for his labor.* These farms are unquestionably too small for the average man following this type of farming. It is only when the size of farm reaches 121 to 160 acres that the

average farmer is able to make a labor income above \$1,000. In our work we must deal primarily with the average farmer and state the conditions under which he can be successful. The unusual man can succeed under much more difficult conditions.

Figure 8 shows the relation between labor income and size of farm in graphic form. The points of the broken line in this figure represent the average size of farm in each of the groups shown in Table XXVI and the average labor income made by each of these groups of farmers. Size of farm is shown at the bottom of the figure and labor income in the left margin. The broken line shows even more clearly than the figures of Table XXVI that as the size of farm increases the average labor income increases, and within the limits

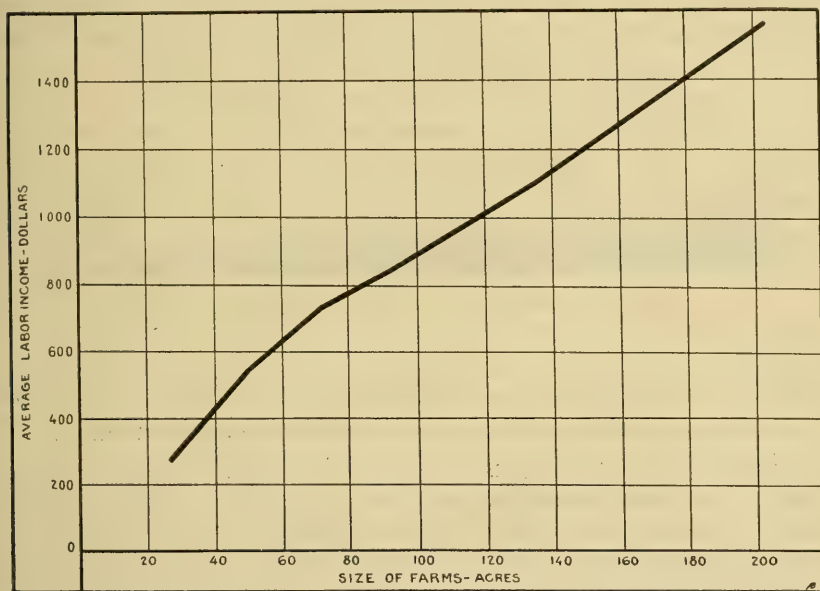


FIG. 8.—Relation of size of farm (area) to labor income; 378 owner farms.

of the sizes found in this survey the increase in labor income keeps pace with increase in area. If the larger farms were devoted to distinctly different types of farming from the small farms, or if there were many farms so large that their owners could not manage them efficiently, there would probably be a different story to tell.

Figure 9 shows quite clearly that size of farm is not the only factor of efficiency in farming. In this figure the labor income of every one of the 378 farms is shown individually. Each of the 378 vertical lines represents the labor income of a particular farm as measured on the scale at the left of the diagram, the highest labor income being approximately \$3,700 on a farm of about 175 acres. In this diagram the farms are arranged according to size, the smallest being

at the right and the largest at the left of the diagram. The line running clear across the lower part of the diagram shows approximately the size of each farm as measured on the scale of acres shown at the left. The largest farm was 393 acres and the smallest 13 acres. The first farm to reach a labor income of more than \$1,000 was a farm of about 37 acres. It was an intensive dairy farm conducted by a very efficient owner. The first farm to reach a labor income of more than \$2,000 was one of 80 acres and of similar type to the smaller farm just mentioned. The first to reach \$3,000 was a farm of 120 acres, which was also a dairy farm, but quite diversified in character, having several other important enterprises. Quite a number of minus labor incomes are shown, represented by the vertical columns projecting downward from the zero line of labor incomes. The largest minus labor income was found on a farm of more than

RELATION OF SIZE OF FARM TO LABOR INCOME

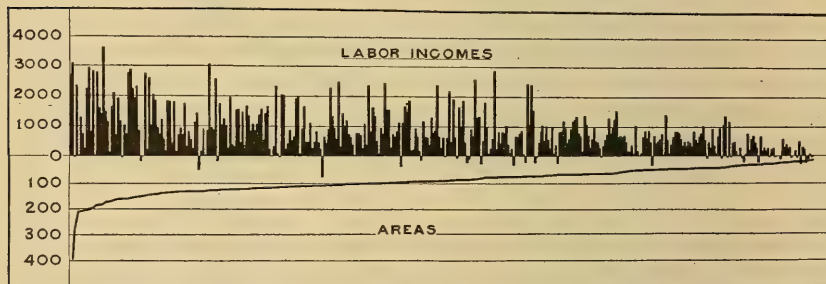


FIG. 9.—Labor income and area of each of the 378 farms operated by their owners.

100 acres and the next largest on a farm of about 120 acres. Thus a large farm presents the possibility of large losses as well as large profits. Size of farm, then, is not sufficient; the farm must be properly organized and efficiently managed and must be devoted to types of farming that are suited to the locality and to the business conditions on the farm. The largest minus labor income shown on this diagram was due to a serious error in the selection of the type of farming.

It will be noticed that many minus labor incomes are shown on the very small farms at the right of the diagram in figure 9. The next largest number of minus labor incomes is found just to the right of the middle of the diagram, on farms of about 70 to 90 acres. These farms were of proper size for a good two-man dairy farm, but for some reason they were not organized in this manner and were consequently not efficient, but some of the most efficient farms found, taking their size into consideration, belong in this group. It will be noticed that there are distinct stages in the increase of the highest labor incomes as we proceed from the small to the large farms in this

diagram. The first marked increase occurs at about 35 acres. Beyond this there is not much change in the maximum labor incomes until we reach about 75 or 80 acres, though the *number of farmers making good incomes* is greater on the average as the size of the farm increases. The 40 to 50 acre dairy farm here represents the efficient size of a one-man farm. From this up to about 75 acres the farms are not large enough for full-sized two-man farms, unless organized and equipped with a good deal of skill. Yet they are too large for one-man farms. A good many of the farms of this size were equipped with two-man outfits, which were not fully utilized. Others were equipped with one-man outfits which could not conduct the business efficiently. This accounts for the fact that a few well-organized and well-conducted farms of about 35 to 40 acres in size were approximately as efficient as any of the farms until we reach about 80 acres. At this point we reach the efficient size two-man farm, and immediately we begin to find farms with much larger labor incomes. Above this we have a group of farms somewhat too large for efficient operation on a two-man basis and somewhat too small for efficient operation on a three-man basis. While the proportion of successful farmers is larger in the upper portion of these limits, there are individual farms around 80 acres which have larger labor incomes than any other farms within the limits here under consideration.

The results shown in figure 9 demonstrate that we must use care in interpreting averages in farm-management surveys. There are other factors which may, in special cases, become more important than magnitude of business. The average labor income of the entire 378 farms operated by their owners is \$789. This is considerably larger than the average labor incomes found in most of our surveys. This, however, does not necessarily mean that the farmers of this locality have better incomes than those elsewhere. The labor income is what is left of the net income of the farm after allowance has been made for interest on the capital invested in the business. The rate of interest used in making these calculations was 5 per cent, which rate is approximately the prevailing rate for well-secured farm loans. But one reason for using this rate was to make it possible to compare the average labor income of farmers in this region with those of others in which this same rate was used.

There is a very distinct tendency for the price of farm property, especially real estate, to rise to such a point as to absorb all the profits in farming except the wages of the operator. The higher labor incomes found in Chester County simply indicate that the farmers of this region had not at the time of this survey (1911-12) fully capitalized the earning power of their property. Under such conditions it is impossible to buy land at the prevailing prices with some degree of certainty that it can be made profitable. As previously

stated, the price of farm land has risen materially in this locality since the survey was made. Unless there has been a corresponding increase in the price of farm products, which is very doubtful, a repetition of this survey would therefore show a decrease in labor incomes, because a larger proportion of the profits would be absorbed by interest on the investment.

RELATION OF SIZE OF FARM TO EFFICIENCY.

In Table XXVII some of the reasons are given why it is easier to make a satisfactory income on a large farm than on a small one. Let us consider first the number of productive work units per farm. On many farms a great deal of the work is devoted to things which add little or nothing to the profits of the business. By productive work we mean work applied to an enterprise which constitutes a source of income, and by a work unit we mean an average day's work of a man or a beast.

TABLE XXVII.—*Relation of size of farm to efficient use of labor and working capital, Chester County owners.*

Sizes of farms, in acres.	Num- ber of farms.	Productive work units per farm.		Crop acres per man.	Man la- bor per crop acre.	Value of labor per month per man.	Crop acres per work horse.	Work horses per man.	Value of ma- chinery per crop acre.	Ratio of cost of buildings to farm income.	
		Man.	Horse.							Dwell- ing.	Other build- ings.
13 to 40.....	54	184	82	13.7	\$20.74	\$23.93	9.0	1.5	\$15.11	3.41	2.78
41 to 60.....	61	299	140	20.2	15.78	26.60	11.9	1.7	12.57	2.19	1.91
61 to 80.....	60	372	177	23.2	13.98	27.12	13.9	1.7	11.92	1.88	1.89
81 to 100.....	68	475	226	25.2	13.46	28.30	14.5	1.7	10.79	1.76	2.03
101 to 120.....	52	551	259	25.6	13.64	29.22	15.0	1.6	11.80	1.83	1.92
121 to 160.....	61	582	286	29.0	11.80	28.50	16.8	1.7	9.20	1.62	1.83
160+.....	22	856	444	31.1	13.05	33.77	17.4	1.8	8.94	1.68	1.91
All sizes..	378	439	211	24.7	13.69	28.27	14.7	1.7	10.88	1.88	1.96

The 54 farms of 40 acres or less furnish their owners on the average 184 productive man-work units and 82 productive horse-work units a year. A man who works at profitable employment only 184 days in the year does not get a good income unless he is a man of unusual ability. These farms are too small to give a sufficient amount of labor with the style of organization which prevails on them. If the region were one which permitted still more intensive farming, these farms might permit a satisfactory business. The third and fourth columns of Table XXVII show that as the farms increase in size the amount of labor the farm provides increases markedly. In the case of the 22 farms of more than 160 acres we have an average of 856 man-work units and 444 horse-work units. It will be noticed that in all the groups the number of productive horse-work units is about half those of the productive man units. On the average for the whole number of farms there are 439 man and 211 horse work units. This increase in the number of produc-

tive work units with increasing size of farm is perhaps the principal reason for the average increase in labor income.

Not only does the large farm furnish a larger amount of profitable labor, but it is easier for the owner to secure more efficient use of labor on the larger farms. That is, he does not have to exert himself so much to find profitable employment for himself and the labor available to him. This is shown in the fifth column of Table XXVII, under the heading "Crop acres per man." Although these farms are all organized in approximately the same manner and, on the whole, are conducted in much the same way, the number of crop acres per man in the group of smallest farms is only 13.7, while on the largest farms it is 31.1 acres, there being a general increase in acres per man with increase in size of farm. On the larger farms the laborers devoted a greater proportion of their time to really profitable employment. This is another reason why the large farm is easier to make profitable than the small one.

The next column of the table, headed "Man labor per crop acre," shows much the same thing, though from a different viewpoint. On the first group of farms—that is, the very small farms—the whole amount of man labor done on the farm costs \$20.74 for every acre of crops grown. This includes all the labor of the farm, not merely the crop labor. As the size of farm increases the amount of the total farm labor per acre of crops gradually decreases until in the next to the last group it amounts to only \$11.80 per crop acre. In the next group it is somewhat larger, these very large farms—that is, for this region—perhaps being somewhat less efficiently managed than the farms somewhat smaller. This column merely shows that on the larger farms the labor is more efficiently applied. The next column, headed "Value of labor per month per man," shows that the larger the farm the more the farmer can afford to pay in wages. The figures in this column are based on wages actually paid and the farmer's estimate of the value of his own labor and that of the unpaid members of his family. The larger farms are able to pay higher wages and, at the same time, make greater profits. The next column shows the crop acres per work horse. Here again we have a great increase in efficiency of work horses as the size of the farm increases, the number of crop acres per work horse being approximately twice as great in the last group as in the first. The column headed "Work horses per man" shows again that the man labor on the larger farms is more efficient than it is on the smaller, the average number of work horses per man increasing with the size of the farm.

When it comes to the matter of expenses the large farms again have the advantage, as shown in the column headed "Value of machinery per crop acre." We shall see later that the small farms are not as adequately equipped with labor-saving machinery as the large

farms. Nevertheless, the necessities of the case require that the expenditure for machinery be nearly twice as much per acre of crops on the smallest farms as on the largest, and there is an almost regular decrease in the value of machinery per acre as the size of the farm increases. A similar state of affairs is shown in the last two columns of the table. On the very small farms the average value of the farm dwellings is 3.41 times, while on the largest farms it is only 1.68 times the net farm income. Similarly, the cost of other buildings is relatively very much larger on the small farms than it is on the large ones, as shown when the value of the buildings is measured in terms of the net farm income. The cost of farm buildings in this area is considerably higher than it is in many other sections of the country. This is due mainly to the fact that farm structures are more substantially built here than is customary in more newly settled sections. It is doubtful, however, in view of the very substantial construction of these buildings, whether the annual cost of maintenance for farm buildings is much, if any, larger than it is in the Middle West, where the buildings cost less but are less substantially built. The amount of money the farmer can afford to put into a building depends in part on the length of time it will last. It may be, therefore, just as cheap in the long run to build a very substantial building that will last a century as to build a much cheaper one that will last only 30 years. While the interest charges are greater on the more expensive building, the depreciation and repairs may be much less. This is a problem which has not yet been worked out fully. We do not know just what proportion of the farmer's income he is justified in putting into farm buildings, though this is one of the important problems under investigation.

Table XXVIII shows another reason why small farms are more difficult to make profitable than large ones. This table shows the annual repair and interest charges on machinery and buildings and the repair charges on fences on farms of different size. In the last column of the table these expenses are combined and reduced to an acre basis.

TABLE XXVIII.—*Relation of size of farm to yearly interest and repair charges on machinery, buildings, and fences on 378 owner farms, Chester County.*

Size of farm, in acres.	Cost per farm.								Cost per acre.
	Machinery.			Buildings.			Fence repairs.	Total per farm.	
	Re-pairs.	Inter-est.	Total.	Re-pairs.	Inter-est.	Total.			
60 and less.....	\$9	\$18	\$27	\$11	\$162	\$173	\$6	\$206	\$5.81
61 to 100.....	14	29	43	11	248	259	8	310	5.80
101 to 160.....	21	37	58	16	308	324	14	396	4.54
Over 160.....	41	53	94	3	493	496	18	608	4.31
Average.....	16	30	46	12	254	266	10	322	5.08

The total expense per acre for these purposes is seen to be \$5.81 on the smallest farms and grows gradually less as the size of the farm increases, and on the largest farms it is only \$4.31.

This matter of the relation of the size of the farm to the ease of making a satisfactory profit has been dwelt upon at considerable length in these pages because of the notion which so widely prevails that the ideal in American agriculture is the small farm. Numerous real-estate promotion schemes all over the country are based on this idea. It is a distinct fallacy. Very small farms are difficult to make successful anywhere, under American conditions, and it is only the exceptional man who is equal to the task. They must always be devoted to the most intensive types of farming, and the products of most kinds of intensive farming fluctuate enormously in volume and price, so that the business is very insecure. The danger is greatly magnified if these small farms are situated a long distance from market, for prices of their products do not have to fall very far until the transportation charges wipe out all profits. Even in the vicinity of the best markets these small farms succeed only in localities where they have distinct advantages for the particular type of farming which they follow.

RELATION OF THE NUMBER OF DAYS WORK PER YEAR TO LABOR INCOME.

In Table XXIX the 378 owner farms are divided into groups based on the number of man work units (or productive days' work) per farm. One hundred and seventeen of these farms had less than 300 man days' work, with an average of 211. These same farmers had an average of 111 horse days' work. This includes only the productive labor of the farm; that is, labor applied directly to a productive enterprise.

TABLE XXIX.—*Relation of the number of productive days' work per farm to labor income, Chester County owners.*

Man work units per farm.	Number of farms.	Man work units per farm.	Horse work units per farm.	Average size of farm.	Labor income.	Adjusted income.
				<i>Acres.</i>		<i>Per cent.</i>
300 and less.....	117	211	111	49	\$336	78
301 to 500.....	129	395	198	88	703	94
501 to 700.....	89	588	278	116	1,083	112
701 and over.....	43	878	378	151	1,668	152
Average.....	378	439	211	90	789	100

The average labor income on this group of farms is \$336, or, figured in percentage, as explained on a previous page, 78 per cent of the average of all the farms. The table shows that as the number of productive work units increases the labor income increases very markedly. Forty-three of these farms had over 700 productive man

days' work, with an average of 878, and 378 productive horse days' work. Their average labor income was 52 per cent above the average of the community.

RELATION OF SIZE OF FARM TO USE OF LABOR-SAVING EQUIPMENT.

Table XXX shows quite conclusively one of the striking disadvantages of the small farm as compared with the large farm. Not only is the relative expense of labor-saving machinery greater on the small farm because of the smaller use that can be made of such machinery, but the small farmer frequently can not afford an adequate equipment, especially in the case of the larger machines and implements.

The region of this survey is one in which the disk harrow is particularly useful.

TABLE XXX.—*Relation of size of farm to use of labor-saving equipment on 378 owner farms, Chester County.*

Size of farms.....acres..	60 and less.	61 to 100.	101 to 160.	Over 160.	All farms.
Number of farms.....	115	128	113	22	378
Items of equipment ^a	Per cent of farms reporting.	Per cent of farms reporting.	Per cent of farms reporting.	Per cent of farms reporting.	Per cent of farms reporting.
Disk harrow.....	22	27	39	64	31
Roller.....	78	91	94	96	88
Corn planter.....	43	63	74	82	61
Grain binder.....	31	70	84	86	63
Grain drill.....	49	74	90	96	73
Hay loader.....	.....	5	23	27	10
Hay tedder.....	51	69	81	86	68
Manure spreader.....	36	65	82	100	63
Silo.....	3	12	24	45	15
Ensilage cutter and feed grinder.....	26	44	50	64	42
Engines.....	23	38	50	64	38
Cream separator.....	16	9	10	5	11

^a Practically all farms reported wagons, buggies, plows, harrows, mowers, rakes, cultivators, and harness.

The soil is rather heavy, and the corn crop is usually planted on sod land. Under such conditions the disk harrow is a valuable implement in preparing the seed bed for corn, as well as for other crops. The table shows that only 22 per cent of the farms of 60 acres or less possess this implement, while 64 per cent of the 160-acre farms and larger have disk harrows. The roller, being a less expensive implement, is found on a much larger percentage of farms, but here again the percentage increases with size of farm. In the case of the corn planter, 43 per cent of the farms of 60 acres and under and 82 per cent of the very large farms own their own machines. The farmers of this community overcome this difficulty to some extent by owning corn planters in partnership, which is a very satisfactory plan, for one corn planter can easily plant in season all the corn needed on three or four of these small farms. The same

is true of the grain binder. On the larger farms grain binders are quite general, and 86 per cent of the big farms own their binders. Only 31 per cent of the small farms have this machine and must depend upon getting a neighbor's machine. Further consideration of the figures given in this table is left to the reader. They show conclusively that the small farms are inadequately equipped, although, as we have already seen, the value of machinery equipment on them is nearly twice as great per acre as it is on the larger farms.

DISTRIBUTION OF CAPITAL ON FARMS OF DIFFERENT SIZE.

Table XXXI shows the average capital per farm, and the per cent of this capital invested in land, dwelling, other buildings, live stock, machinery, feed, and supplies, and cash to run the farm, for each of the size groups. The last two lines of the table give similar data for 124 tenant farms and 27 special farms. Considering first the farms operated by their owners, the average capital of the entire 378 farms is \$10,486; on the 54 farms of 13 to 40 acres it is \$4,453, increasing gradually to \$23,124 on the 22 farms of over 160 acres. The fourth column of the table shows another reason why it is easier to make a profit on a large farm than a small one.

TABLE XXXI.—*Distribution of farm capital on owner, special and tenant farms, Chester County (per cent).*

Size of farm in acres.	Number of farms.	Average capital.	Land.	House.	Other buildings.	Live stock.	Machinery.	Feed and supplies.	Cash to run farm.
			<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>
13 to 40.....	54	\$4,453	13.3	35.4	28.9	12.2	6.4	2.5	1.3
41 to 60.....	61	6,486	20.9	29.4	25.8	13.8	6.4	2.4	1.3
61 to 80.....	60	8,948	26.8	24.7	24.9	13.4	6.1	2.7	1.4
81 to 100.....	68	11,045	28.5	22.4	25.6	14.0	5.7	2.4	1.4
101 to 120.....	52	12,461	28.7	22.9	24.1	14.2	6.2	2.9	1.0
121 to 160.....	61	14,478	34.8	20.4	23.0	13.2	5.0	2.4	1.2
Over 160.....	22	23,124	34.3	19.9	22.5	14.9	4.6	1.9	1.9
Total average..	378	10,486	28.8	23.5	24.5	13.7	5.6	2.5	1.4
Tenant farms.....	124	12,030	33.3	22.0	21.5	14.6	5.3	2.3	1.0
Special farms.....	27	12,893	19.6	30.0	31.9	8.8	5.2	1.9	2.6

The large farms have a markedly greater proportion of their capital devoted to land, which is the foundation of the farm business. On the other hand, the small farms have a very much greater percentage of their capital invested in buildings. The percentage of investment in live stock is approximately the same in all the groups, which merely shows the similarity in type of farming and in farm organization on farms in this region. The percentage of investment in machinery decreases slightly as the farms increase in size. The proportion of the capital represented by feed and supplies is approximately the same in all the groups except the very largest, where it

is somewhat smaller. The percentage of the capital represented by cash kept on hand for current expenses does not vary greatly.

We shall later see that the tenants in this area make a considerably larger labor income than owners. The principal reasons for this will be discussed later, but one of them is shown in this table. On the tenant farms the proportion of the capital invested in land is considerably larger than it is on owned farms. This is mainly due to the fact that the tenant farms are on the average larger than the owned farms. The percentage of investment in live stock is somewhat greater on the tenant farms, and the amount of cash to run the farm is somewhat smaller. The 27 special farms, which vary from farms of a few acres to some very large farms with a hothouse business which is merely incidental to the general farm business, have an average capital of \$12,893, considerably larger than that of the owner farms and about equal to the total capital—that is, investment of both landlord and tenant—on the tenant farms. But the percentage of capital invested in buildings on the special farms is much larger than it is on the others, while that in live stock is much smaller. The percentage of cash required for current expenses on these special farms is nearly twice as great as on owned farms and two and a half times as great as on the tenant farms.

EFFICIENCY AS MEASURED BY INCOME ON CAPITAL.

In the preceding pages the markedly greater efficiency of the large as compared with the small farm has been clearly demonstrated when considered from the standpoint of the labor income of the farmer; but when we consider the subject purely from the standpoint of the interest on capital invested the story is a different one, as is seen in Table XXXII. In most parts of Europe this matter is considered from the latter standpoint only.

TABLE XXXII.—*Income on capital on 378 owner farms, Chester County.*

Area groups, acres..	{ 13 to 40	41 to 60	61 to 80	81 to 100	101 to 120	121 to 160	Over 160	} Total	{ Total tenant.	Total special.
Number of farms....	54	61	60	68	52	61	22	378	124	27
Percentage farm income is of capital invested.....	10.4	13.5	13.2	12.7	12.5	12.6	11.8	12.5	13.5	17.9
Percentage of income on investment when value of farmer's labor is deducted.....	4.3	8.6	9.8	9.7	9.8	10.2	9.8	9.4	10.4	14.7

The agriculture of Europe is based mainly on income per acre. In America more attention is given to income per farm family. The reader is left to himself to judge whether it is better for the country

as a whole that our agriculture should be efficient from the standpoint of the people on the farm or from the standpoint of the capitalist who owns the land. Fortunately, as yet, in this country the capitalist and the farmer are frequently the same, but even where this is the case it is the income per farm family rather than the percentage of profit on the capital invested which makes for good citizenship in the country and for a high standard of living on the farm.

In making the calculations the results of which are shown in Table XXXII the farm income is first reduced to percentage of capital invested. In the first line of the table the value of the farmer's labor is left out of consideration, the entire net income being treated as the percentage of profit on capital invested. There is seen to be relatively little variation in the figures for different sizes of farms except that in the smallest and the largest groups the figures are somewhat smaller than in the intermediate sizes, and in these intermediate sizes the two smallest show a somewhat larger percentage profit than the three groups of larger farms. The last line of the table was calculated by using the farmer's own estimate of the value of his labor, subtracting this amount from the net farm income, and then expressing the remainder as percentage profit on capital invested. This method corresponds to that usually used in industries where everyone connected with the business receives a salary. The average percentage profit calculated in this manner is 9.4 per cent for the 378 farms operated by their owners. Except for the farms of 40 acres and less, there is comparatively little variation in the profits. It is because profits have so often been figured in this manner that the public has been misled as to the advantages of the large as compared with the small farm. It is interesting to note, as shown in next to the last column of Table XXXII, that the percentage profit on the tenant farms calculated by both methods is larger than it is on the owner farms. We shall later see the reason for this.

The year in which this survey was made happened to be one which was rather favorable to the mushroom business and the average profits made by farmers who grow mushrooms were considerably larger than those of the more usual types of farming in this region, as is seen by the last column of Table XXXII. There are, however, years in which the reverse is very distinctly the case.

DISTRIBUTION OF PRODUCTIVE WORK UNITS.

Table XXXIII gives some interesting data on the relative proportion of the productive labor devoted to crops, live stock, and miscellaneous purposes on the farms operated by their owners. There is

seen to be very little variation on farms of different size except that on the larger farms there is a smaller proportion of the miscellaneous productive work. On the average about 41 per cent of the productive man labor is devoted to crops, 57 per cent to live stock, and a little more than 2 per cent is miscellaneous work.

TABLE XXXIII.—*Relation of size of farm to distribution of productive work units, Chester County owners.*

Size of farm in acres.	Per cent of man work units on—			Per cent of horse work units on—		
	Crops.	Stock.	Miscellaneous.	Crops.	Stock.	Miscellaneous.
40 and less.....	40.1	55.1	4.8	80.8	15.9	3.3
41 to 60.....	40.5	55.3	4.2	79.6	17.0	3.4
61 to 80.....	39.7	57.2	3.1	80.9	15.5	3.6
81 to 100.....	40.5	56.0	3.5	82.6	15.5	1.9
101 to 120.....	39.5	59.6	.9	81.2	16.9	1.9
121 to 160.....	41.1	57.8	1.1	82.5	15.4	2.1
161 and over.....	44.6	54.6	.8	84.3	13.7	2.0
Average.....	40.8	56.9	2.3	81.9	15.7	2.4

In the case of the productive horse labor, about 82 per cent is devoted to crops, about 16 per cent to live stock, while somewhat more than 2 per cent is miscellaneous in character. The proportion of productive labor devoted to live stock is much larger in this region than it is in many other sections of the country.

TENANT FARMS.

Twenty-four per cent of the farms analyzed in this survey were operated by tenants. This is a much smaller proportion than is found generally in this country. This is accounted for mainly by the relatively small size of the farms. When the owner of one of these small or middle-sized farms rents it out, moves to a near-by village, and undertakes to live on the income from his farm he finds this income insufficient to meet his wants. Hence, it is customary for the farm owner to operate his own farm until advancing age compels his retirement. He is then usually superseded by a member of his own family and retains his residence on the farm.

RELATION OF TENURE TO SIZE OF FARM.

The tenant, even when he owns his own working capital, or half of the principal investment, which in this case is usually dairy cows, has a comparatively small investment. His income is therefore limited to what the farm furnishes toward the family living, what he gets for his labor, and the relatively small income for his invested capital. In order to provide a satisfactory income he must conduct a business of considerable magnitude. Tenants of the better class, therefore, tend to avoid small farms, because of the difficulty of

securing a satisfactory living on them. This is clearly shown in Table XXXIV. The percentage of the 13 to 40 acre farms operated by tenants is only 16, while of the farms of 160 acres or more 41 per cent are operated by tenants. The better class of tenants thus wisely choose the largest available farms for which their working capital is adequate.

TABLE XXXIV.—*Relation of the tenure to size of farm on 529 farms, Chester County, Pa.*

Size of farms in acres.	Total number of farms.	Per cent operated by owners.	Per cent operated by tenants.	Per cent of special farms.
13 to 40.....	76	71	16	13
41 to 60.....	77	79	18	3
61 to 80.....	80	75	21	4
81 to 100.....	91	75	21	4
101 to 120.....	71	73	21	6
121 to 160.....	93	66	32	2
Over 160.....	41	54	41	5
Total.....	529	71	24	5

This same table shows the percentage of farms of different sizes operating hothouses. The largest percentage is found in the group of smallest farms. In the remaining groups there is not much difference, an occasional farm in each group maintaining a hothouse business.

Table XXXV shows similar data for the entire State of Pennsylvania, for Chester and Lancaster Counties, and for the entire State of Oregon. In general, as the size of the farm increases the percentage of farms operated by tenants increases, within rather wide limits.

TABLE XXXV.—*Relation of tenure to size of farm (census data).*

Size of group.	Percentage tenants of all farmers.			
	Pennsylvania.			Oregon.
	The State.	Chester County.	Lancaster County.	
All sizes.....	23.3	27.6	37.2	12.7
Under 20 acres.....	16.8	16.9	30.0	13.4
20 to 49 acres.....	16.8	21.5	26.6	13.3
50 to 99 acres.....	22.7	27.2	44.9	12.7
100 to 174 acres.....	31.4	38.6	54.0	19.2
175 to 499 acres.....	30.2	44.2	57.3	23.7
500 to 999 acres.....	19.3	(a)	(b)	17.2
1,000 acres and over.....	21.0			15.1

^a Chester County, 500 to 999 acres, reports 12 farms and 1 tenant farm.

^b Lancaster County, 500 to 999 acres, reports 2 farms and 1 tenant farm.

There are sections of the country, however, in which the reverse is true, but they are sections in which the tenants represent a dependent class with little or no working capital, because of which fact they are compelled to occupy practically the status of hired laborers. In gen-

eral, where the tenant class has little or no working capital a tenant is unable to select a farm with reference to the ease of making a satisfactory income. Under such conditions it is frequently found that the average size of tenant farms is considerably less than that of owned farms, and the percentage of tenancy frequently decreases as the size of the farm increases, especially if the prevailing type of farming is somewhat intensive.

TYPES OF FARMING ON TENANT FARMS IN CHESTER COUNTY.

Table XXXVI shows that in the main the types of farming found on tenant farms in Chester County, Pa., are the same as on the farms operated by their owners, the principal differences being that on the tenant farms a larger percentage of the receipts is obtained from the dairy business.

TABLE XXXVI.—*Comparison of types of farming on farms operated by tenants and those operated by owners, Chester County.*

	Percentage of receipts.		Percentage of acreage in crops.	
	Owner.	Tenants.	Owners.	Tenants.
Dairy cattle and their products.	44.1	53.8	.....	.....
Beef.	1.5	.2	.....	.....
Horses.	.4	.9	.....	.....
Hogs.	2.8	2.3	.....	.....
Sheep and wool.	.5	.1	.....	.....
Poultry and eggs.	8.2	6.7	.....	.....
Corn.	2.3	2.4	22.3	24.6
Potatoes.	8.9	6.9	6	5.9
Wheat.	8.5	7.9	18.2	18.7
Oats.	.2	(a) 10.6	6.4	5.6
Hay.	14.3	10.6	44	42.9
Fruit.	.7	.5	2.5	1.9
Truck crops.	.5	.2	.3	.1
Special.	b .1	c .3	(a) .3	.....
Miscellaneous.	7.0	7.2	.3	.3
	100.0	100.0	100.0	100.0

a Less than one-tenth of 1 per cent.

b Sweet peas, 1 farm; tobacco, 1 farm.

c Tobacco farm.

On account of the fact that the tenant farms are somewhat more heavily stocked, there is also a slightly larger percentage of acreage in corn. These are the only conspicuous differences in type between the two classes of farms.

LABOR INCOMES ON OWNER AND TENANT FARMS.

The average net income of the landlords who own the 124 tenant farms here under consideration was, for the year 1911, 7.3 per cent of their invested capital. In comparing the labor income of owners and tenants in the same locality, the fairest comparison is made when the interest on capital is estimated in both cases on the basis of the interest received by landlords. Such a comparison is made in Table XXXVII between the 378 farms operated by their owners and the 124 tenant farms found in this survey. When capital is allowed an

income of 7.3 per cent, the average labor income of the 378 owners is \$548. Under similar conditions the average labor income of the 124 tenant farmers is \$739.

TABLE XXXVII.—*A comparison of the labor income of owners and tenants by allowing 7.3 per cent interest on the total farm investment, instead of 5 per cent (7.3 per cent is the average rate of the landlord's interest on investment); survey 1912, Chester County.*

	Number of farms.	Number of acres.	Per farm.		
			Capital.	Farm income.	Labor income.
Owners.....	378	90	\$10,486	\$1,313	\$548
Tenants.....	124	106	12,030	1,617	739

Approximately half of this difference is due to the fact that the tenant farms on the average are more than one and one-fourth times as large as the average of the owned farms, but part is also probably due to the fact that the tenant farms on the average have a larger number of dairy cows, usually of somewhat more than average quality. While these tenants make larger labor incomes than the owners, it must be remembered that the owners have the interest on their investment in addition to this labor income, so that the owner's families have larger total incomes than those of the tenants.

This bulletin contains ample evidence that the young farmer who has relatively little capital will find it to his best interests to become a tenant on a farm of considerable magnitude rather than to undertake the same type of farming on a much smaller farm which his capital might enable him to own.

RELATION OF TENANTS' LABOR INCOME TO SIZE OF FARM AND TO TYPE OF TENANCY.

Of the 124 tenants whose business was analyzed in this survey 53 were cash and 71 share tenants (see Table XXXVIII). On the whole, the average size of farms operated by cash tenants was smaller than that operated by share tenants.

TABLE XXXVIII.—*Relation of size of farm to tenant's labor income, capital allowed 5 per cent interest.*

Size of farm, in acres.	Cash tenants.			Share tenants.		
	Number of farmers.	Average capital.	Labor income.	Number of farmers.	Average capital.	Labor income.
60 and less.....	17	\$1,024	\$487	9	\$925	\$428
61 to 100.....	15	2,219	807	21	1,713	499
101 to 160.....	14	3,696	1,411	31	2,371	766
161 to 200.....	7	4,219	1,499	10	2,857	944
Average.....	53	2,490	954	71	2,061	669

Nevertheless the cash tenants made an average labor income of \$954 as compared with \$669 for the share tenants, allowing capital 5 per cent interest. As was to be expected, the cash tenants had on the average considerably more capital than the share tenants. The share tenant is usually such because of the small amount of his capital. The tenant who has capital enough to pay cash rent for a farm approximately as large as he wants is inclined to do so because of the greater freedom he thus acquires in his farm operations. He has greater economic independence than the share tenant, and in order to be able to pay cash rent he selects on the average a somewhat smaller farm. From the standpoint of the tenant cash rent is more satisfactory than share rent. From the standpoint of the landlord the reverse is true. In the case of the share renter the landlord is entitled to a larger income on his investment because of the greater responsibility he assumes. For similar reasons the cash tenant is entitled to and receives a larger income than the share tenant.

Table XXXIX shows the relation of the landlord's profits to the size of farm and to the type of tenancy. There is not much difference in the percentage of the landlord's income on farms of different size, except in the case of the very small farms, where the landlord's income is less for both types of tenancy. In the case of the cash tenant the average profits of the landlord are only 3.92 per cent on his investment, while in the case of the share tenant it is 8.81 per cent.

TABLE XXXIX.—*Relation of size of farm to landlord's profits on 124 farms operated by tenants.*

Size of farms, in acres.	Per farm.					
	Cash rent.			Share rent.		
	Number of farms.	Average capital.	Per cent on investment.	Number of farms.	Average capital.	Per cent on investment.
60 and less.....	17	\$3,581	3.09	9	\$6,370	6.91
61 to 100.....	15	6,231	3.53	21	9,181	8.02
101 to 160.....	14	10,010	4.39	31	12,777	9.48
161 to 200.....	7	11,557	4.15	10	19,263	8.82
Average.....	53	7,082	3.92	71	11,803	8.81

The actual amount of the landlord's income increases, therefore, in about the same proportion as the size of the business increases, while the percentage profit remains approximately constant. The tenant's labor income, as was shown in Table XXXVIII, increases markedly with increase in the size of the business, as was found to be the case on farms operated by their owners.

RELATION OF TENURE TO YIELD OF CROPS.

The first line of Table XL gives the average yields of the crops grown in this area on farms operated by their owners, the second line yields on the tenant farms taken as a whole. As is to be expected, yields on the farms operated by their owners are slightly larger on the average than those operated by tenants, but the difference is not great. The last two lines of the table give a comparison of the yields on farms operated by cash tenants and those operated by share tenants. Except in the case of silage, the yields are in all cases larger on the farms of share tenants, the difference probably being due to the greater amount of control the landlord retains of the business in the case of share-rented farms.

TABLE XL.—Comparison of crop yields per acre on owner and tenant farms, Chester County.

	Number of farms.	Corn.	Silage.	Potatoes.	Wheat.	Oats.	Hay.
Owners.....	378	65.3	13.1	78.8	24.8	41.6	1.3
All tenants.....	124	64.5	11.7	66.4	23.6	37.1	1.25
Cash rent.....	53	61.8	12.1	54.9	22.0	36.2	1.2
Share rent.....	71	66.1	11.4	72.7	24.6	37.6	1.3

The average yield of corn on the share-rented farms is actually larger than it is on the owned farms, the yield of hay being approximately the same, while in the case of the other crops the owners have more or less the advantage in the matter of yield.

QUALITY OF BUSINESS.

A very important factor of efficiency in farming is the quality of the business. This is indicated by the yield per acre, the income per animal unit, work units accomplished per individual employed, etc.

YIELD PER ACRE.

Table XLI shows the average yield per acre of the principal crops on the 378 farms operated by their owners, by size of farm. Some of these yields are very high, while others are low. The average yield of corn was 65.3 bushels per acre, which is far above the average for any of the corn-belt States as a whole, and there are few localities in any State that exceed this. The yield of silage is correspondingly high, being 13.1 tons per acre, or an average of 1 ton for each 5 bushels of corn. The season of 1911 was very favorable to the corn crop, and this yield is somewhat above the average for this locality. The yield of wheat is satisfactory when compared with State averages

and the average of the country as a whole. The soils of this region appear to be particularly adapted to corn and wheat, though such yields are not obtained by careless methods. There are few localities where farmers make better use of manure than in Chester County or where more manure is produced per acre of crops grown. We shall later see that these farmers get much greater results from a given amount of manure than is the case in some other sections.

The yield of oats here is fair, the average being 41.6 bushels per acre; but here, as in most other localities, the production of nutriment per acre is small compared with other crops grown for feed. The low price of this cereal and the small production per acre make it an unprofitable crop in this section, and it is gradually being discarded by the better class of farmers.

The yield of potatoes is distinctly low. The soil is poorly adapted to this crop. While potatoes should be raised for home consumption, and probably for sale to a limited extent, it is probable that farmers having soils similar to those of this area would not find it advantageous to make this a major crop.

The yield of hay in this region was lower than average in 1911. The average of 1.3 tons per acre is only just equal to that of the country as a whole. The pastures here are among the most productive in the country. The low yield of hay was due mainly to unfavorable weather during the early part of the season, but the practice of leaving hay fields down more than two years, which is not infrequent here, also lowers the average. The first-year hay field usually produces an excellent crop, but if the field is cut for hay for three or four years the yields become very low. By using a somewhat larger proportion of the available manure as a top dressing for hay fields, or possibly by a somewhat more liberal use of commercial fertilizers on these fields, the yield of hay should be materially increased. This would give a better sod to turn under for corn, and this should compensate for the slight loss of manure to the corn crop due to the use of more manure on the hay fields. Hay is one of the most profitable crops in this region, and it should be profitable to go to the necessary expense to produce better yields than are now obtained on the average farm.

RELATION OF YIELD PER ACRE TO SIZE OF FARM.

The plea for small farms has often been made on the basis of the better yields it is possible to obtain by the better tillage that can be given to small areas. It is not questioned that better yields could be thus obtained, but the fact is that American farmers have thus far found it to their advantage to spread their work over more acres rather than to increase unduly the amount of work per acre. Within

proper limits they make more profit by this procedure. The figures of Table XLI show that as a rule the farmer who tills a small acreage does not get better yields than those who till larger areas, at least within the limits of the areas found in this study.

TABLE XLI.—Yield of crops per acre on 378 owner farms, Chester County.

Acres.	Number of farms.	Corn.	Silage.	Potatoes.	Wheat.	Oats.	Hay.
40 and less.....	54	62.2	10.8	72.1	25.1	37.0	1.4
41 to 60.....	61	67.2	12.0	81.5	25.3	38.0	1.5
61 to 80.....	60	64.6	15.3	78.2	25.6	44.8	1.4
81 to 100.....	68	64.5	12.7	79.6	24.1	43.0	1.3
101 to 120.....	52	66.7	12.6	76.1	24.8	42.9	1.3
121 to 160.....	61	66.0	12.5	75.8	24.3	41.4	1.3
Over 160.....	22	64.7	13.7	88.1	25.8	38.0	1.3
Average.....	378	65.3	13.1	78.8	24.8	41.6	1.3

There appears to be very little relation on these farms between size of farm and yield per acre.

RELATION OF YIELD PER ACRE TO LABOR INCOME.

While Table XLI shows very little relation between size of farm and yield per acre, Table XLII shows that within certain very wide limits there is a very distinct relation between yield per acre and labor income: The *crop index*, which is used as a measure of the yields on a given farm, is found as follows: Suppose a given farm produces—

500 bushels of corn on 10 acres;

200 bushels of wheat on 10 acres;

25 tons of hay on 20 acres;

—
A total of----- 40 acres.

Suppose, further, that the average yields in the locality are such that, on the average, farmers produce—

500 bushels of corn on 7.7 acres (65 bushels per acre);

200 bushels of wheat on 8.0 acres (25 bushels per acre);

25 tons of hay on 16.7 acres (1.5 tons per acre);

—
A total of----- 32.4 acres.

The crop index of the farm in question is now found by dividing 32.4 by 40; that is, by dividing the average acreage in the community by the actual acreage on this farm required to produce the quantities of these products which this farm produces. In this case the crop index is 0.81. Roughly speaking, this means that the yields on this farm are 81 per cent of the average of the community.

In Table XLII the owner farms are divided into groups according to the crop index of each farm.

TABLE XLII.—*Relation of crop index to labor income and adjusted income (per cent) ; 378 Pennsylvania owners.*

Crop index.	Number of farms.	Average labor income.	Average adjusted income.	Average size of farms.
			<i>Per cent.</i>	<i>Acres.</i>
84 and less	75	360	49	89
85 to 99	91	616	74	90
100 to 114	107	870	108	89
115 to 139	92	1,183	153	91
140 and over	13	1,005	130	82
Total	378	789	100	90

There were 75 farms on which the crop index was 84 or less. The average labor income of these 75 farms, when adjusted for size of farm, was just 49 per cent of the average for the whole number of farms.

As the crop index increases the labor income is seen to increase until near the limit of yields found in this survey. But the 13 farms having a crop index of 140 or more had smaller labor incomes on the average than the next lower group. The number of farms in this group is too small to permit very positive conclusions on this point, but these results are consistent with those found in other surveys. Ordinarily it pays well to increase crop yields till they are considerably above the average, but a limit is finally reached beyond which it does not pay to go. Good yields are ordinarily more profitable than extremely high ones, and decidedly more profitable than very small yields.

The last column of Table XLII shows again that there is here very little relation between size of farm and yield per acre. The small farms on the average make just about the same yields per acre as the large ones, and it does not pay their owners to apply the necessary additional labor and materials to increase these yields very materially. In the case of certain crops, however, especially hay, it would probably pay the average farmer in this region to go to the necessary expense to secure a considerable increase in yield. *In general, if crop yields are low, it usually pays to increase them.*

RECEIPTS PER COW AS RELATED TO LABOR INCOME.

Table XLIII shows that the income per cow is a very important factor in the profitableness of farming in this region, as it is wherever such studies have been made. Since dairying is the principal business of the farmers in Chester County, the income per cow is

even more important here than in a region where fewer cows are kept.

TABLE XLIII.—*Relation of receipts per cow to labor income, Pennsylvania owner farms.*

Divided according to receipts per cow.	Five and more cows.			
	Number of farms.	Receipts per cow.	Adjusted income.	Labor income.
			<i>Per cent.</i>	
50 and less	48	\$42	55	\$418
51 to 60	43	68	102	592
61 to 70	27	57	92	783
71 to 80	51	75	99	782
81 to 90	24	86	111	831
91 to 100	39	96	137	1,185
101 to 120	29	110	162	1,422
Over 120	28	138	175	1,602
Total.....	289	80	111	906

Within the limits found in this survey the labor income increases markedly as the income per cow increases. Forty-eight farmers received \$50 or less income per cow. Their labor income was 45 per cent below the general average. Twenty-eight farms had incomes per cow of more than \$120, and their labor incomes were 75 per cent above the average.

It is possible to overdo in this direction also, just as it is in the matter of yield per acre, but no farmers were found in this survey who went to too great an expense to get high yield of product per cow. The results of this survey show very clearly that the farmers of Chester County can increase their profits more markedly and more certainly by improving the quality of their cows than in any other way. On farms maintaining large herds this can be done easily enough by using the right kind of bulls. But on the smaller farms this is not always feasible. The right kind of bulls cost so much that the small farmer can not afford them. This difficulty can best be overcome by cooperative ownership of good bulls. Cow-testing associations should be organized, not only as a means of finding which cows are worth keeping and which should be disposed of, but also as a means of providing good breeding stock. With such organizations a good bull can be passed from farm to farm, and thus retained in the neighborhood as long as he is serviceable.

One difficulty in the past has been the fact that so few farmers raised their cows. In order to maintain herds and keep up their quality, it is necessary to replace yearly an average of about one-fourth of the herd. The number of heifer calves saved annually must, therefore, be about 25 per cent of the number of cows kept. In this locality the farmers raise an average of only 8.2 per cent as

many heifers a year as they have cows. The remainder of the needed animals are obtained by purchase. The herds can not be materially improved as long as this practice continues; but, as already stated, the prices which it is now necessary to pay for cows in this region are becoming so high that farmers are beginning to raise a larger proportion of their cows. This is perhaps fortunate, for it gives a better chance to improve the quality of the herds.

Because of the large proportion of cows bought, there is considerable mixture of breeds in this region, much more so than would ordinarily be the case where farmers raise their cows. When the practice of raising cows again becomes common, as it seems to bid fair to do, it is important that particular attention be given to the matter of breeds, and more especially to securing bulls from the best producing cows. Every dairy farmer in this region should get firmly fixed in mind the idea that improvement in the producing capacity of cows means increased profits, provided, of course, the ordinary dairy farmer does not have to pay exorbitant prices for the right kind of breeding stock.

The facts given in Table XLIV emphasize strongly the point here under consideration. In this table those farmers who secured \$50 or less income per cow are divided into three groups, according to the number of cows in the herds. With cows of this quality, or rather lack of quality, the larger the herd the less the profit.

TABLE XLIV.—*Relation of receipts per cow and number of cows to labor income on commercial dairy owner farms, Chester County.*

Receipts per cow.	Number of cows per 100 crop acres.	Number of farms.	Average number of cows.	Average income per cow.	Labor income.	Adjusted labor income, per cent.
50 and less.....	1 to 16.9....	14	13.7	43.1	405	52
	17 to 22.9....	20	19.5	41.2	369	46
	23 to 28.9....	11	26.8	45.3	258	32
100 plus.....	1 to 16.9....	15	11.2	137.5	1,090	112
	17 to 22.9....	7	19.9	119.7	1,426	182
	23 to 28.9....	14	25.4	119.3	1,566	184
	29 plus.....	23	40.1	125.8	1,723	197

The last part of the table refers to those farmers who secured incomes per cow in excess of \$100 per annum. Here, as the herds increase in size, the labor income increases rapidly. This merely goes to show that very poor cows do not pay, while high-grade cows are quite profitable under the conditions prevailing in this area.

COMBINED EFFECT OF YIELD PER ACRE AND INCOME PER COW.

Table XLV shows the combined effect of yield per acre and income per cow. Thirty-four farms have incomes of \$60 or less per cow and a crop index of 90 or less. Their average labor income is

47 per cent of the general average. Forty-six farms have cows that produce over \$90 worth of products per year and crop yields more than 10 per cent above the average. Their labor incomes average 85 per cent above the general average. Large income per cow is slightly more important in securing a profit than is large yield per acre, but both are important.

TABLE XLV.—*Relations of receipts per cow and crop index to adjusted labor income on 378 owner farms, Chester County.*

Crop index.	Receipts per cow.					
	60 and less.		61 to 90.		91 and more.	
	Number of farms.	Adjusted income.	Number of farms.	Adjusted income.	Number of farms.	Adjusted income.
		<i>Per cent.</i>		<i>Per cent.</i>		<i>Per cent.</i>
90 and less.....	34	47	32	70	18	89
91 to 110.....	28	56	57	103	37	148
111 and more.....	22	108	36	136	46	185

Farms having cows that produce less than the average should pay special attention to the improvement of their herds, and those which have less than the average yields per acre should give special attention to this point. It is easier to improve poor cows than it is good ones, and it is easier to increase low yields than it is high ones. It is also more profitable.

It is very rare indeed to find a farm excelling in all the factors of efficiency here mentioned that does not make a good profit. Thus, if a farm is devoted to a type of farming adapted to its conditions, is large enough to give full employment at all seasons of the year to the farmer and the labor available to him, has good yields, large income per animal unit, and is adequately and economically equipped, it is almost certain to be profitable. The fewer of these points in which a farm excels the more difficult it is to make it profitable.

EFFICIENCY OF FARM LABOR.

A work unit is the average amount of work done in a day by the average workman. Some men do much less and some do much more than this. Some men also have their work so organized that a given amount of effort accomplishes more work than the average. In Table XLVI the 378 owner farms are classed according to the amount of productive work accomplished per year on them by each individual employed. It is assumed that the farmer himself accomplishes as much work in a year as the average of those employed on his farm. The table shows that there were 22 of these farms on which the average work done per individual employed is less than 100 ordinary days of productive work. The average labor income of these farmers is \$181, or \$2.18 per unit of productive labor. It is

probable that these men really worked at productive labor more than a hundred days during the year, and that many of them did more work on some of their crops than was profitable, for their average yields are above the average of the community. (See next to last column of table.) They also probably spent too much of their time doing things that had no relation to the farm income. That these men were poor managers is shown by the fact that their cows brought them only \$27.60 per head for the year's product.

TABLE XLVI.—*The relation of productive work units per man to profits and other factors in farming on 378 owner farms, Chester County.*

Productive work units per man.	Average per man.	Number farms.	Average size.	Productive work units per horse.	Labor income.	Receipts per cow.	Crop index.	Labor income of operator per day of productive labor.
			<i>Acres.</i>					
Less and 100.....	83	22	58	38.5	\$181	\$27.60	103	\$2.18
100 to 149.....	126	62	72	45.2	366	46.80	102	2.90
150 to 199.....	176	114	90	55.8	625	72.00	98	3.55
200 to 249.....	222	102	96	59.1	959	78.00	105	4.32
250 to 299.....	272	49	108	62.7	1,147	78.50	100	4.22
300 to 399.....	336	23	107	63.2	1,535	77.00	109	4.57
400 and over.....	448	a 6	101	66.7	1,833	83.00	107	4.09
Average.....	201	378	90	78.3	789	68.20	100	3.93

^a One farmer out of the six met with serious loss for which he was not responsible, thus causing a minus labor income of \$49. The average labor income of the other five was \$2,209, with an average wage of \$4.93 per work unit.

At the other extreme we have 23 farms on which there was an average of 336 productive work units done per year by each person employed. This does not necessarily mean that each person actually worked 336 days in the year at productive labor, but it does mean that the work accomplished was equivalent to this many ordinary days' work. The owners of these 23 farms made, on the average, \$4.57 wages for each productive work unit, as compared with the \$2.18 made by the first group. There were six farms (see next to last line of the table) on which the amount of productive labor accomplished averaged 448 ordinary days' labor per year for each man employed. These farms were unusually well managed, and little time was wasted at unproductive work. The owner of one of the six had the misfortune of having contagious abortion get into his herd and had a minus labor income of \$49 for the year, but the other five made an average labor income of \$2,209, or \$4.93 per unit of productive work done.

The income per cow is also much larger on these farms where each workman accomplished a large amount. As would naturally be expected, the average productive work units per horse also increases with increase of work units per man (see fifth column of table).

The fourth column of this table shows that within certain limits the work units per man bears a close relation to the size of the farm. It is on the farms of 100 acres or less that the small number of productive work units per man is found. For farms larger than this there does not appear to be much relation between size of farm and productive work units per man. In other words, with the type of farming and the general farm methods which prevail here, the farm of about 100 acres appears to be the minimum efficient economic unit from the standpoint of the proportion of productive work as compared with miscellaneous work.

FARM ORGANIZATION.

We have already seen that in the Chester County survey area most of the farms are more largely devoted to dairying than to any other enterprise. Yet only 157 of the 378 farms conducted by their owners had sufficient income from dairy products to be classed as real dairy farms. In other words, although this is distinctly a dairy region it is by no means exclusively so. There is considerable diversity in the local farming.

DIVERSITY INDEX.

In order to ascertain to what degree this diversification of enterprises is justified by local experience, it is desirable to have a definite means of measuring the degree of diversification on a farm. The diversity index furnishes such a means. When the enterprises on a farm are all equally important or of equal magnitude the number of these enterprises may be used as the measure of diversity. Thus, if a farm business is based on three equally important enterprises, its degree of diversity is said to be three. But if the enterprises on a farm are of unequal magnitude, the degree of diversity may be determined as follows: First, find the sum of the magnitudes of all the enterprises (in most cases the receipts from an enterprise may be taken as its magnitude),¹ divide the magnitude of each enterprise by the sum above mentioned, square each of the quotients, and divide unity by the sum of these squares. The result is the diversity index.

In Table XLVII the 378 owner farms are divided into groups based on the degree of diversity of their business. Seventy-nine of these farms had a degree of diversity less than 3. Their average labor income, when adjusted to eliminate the effect of size of farm, was 18 per cent below the general average. On 107 farms the diversity index was from 3 to 3.9. Their labor income was 10 per cent below the general average.

¹ The most accurate measure of the magnitude of an enterprise is the total cost of its conduct, including interest, depreciation, wages, repairs, materials, etc.

TABLE XLVII.—*Relation of diversity index to labor income, 378 Pennsylvania owners.*

Diversity index.	Number of farms.	Average labor income.	Average adjusted income.	Average size of farms.
			<i>Per cent.</i>	
Less than 1 to 2.9.....	79	\$663	82	83
3 to 3.9.....	107	718	90	90
4 to 4.9.....	125	888	114	94
5 and over.....	67	866	112	90
Total.....	378	789	100	90

On 125 farms the diversity index was 4 to 4.9. These made labor incomes 14 per cent above the average. The remaining 67 farms had a degree of diversity of 5 or more. Their labor incomes were 12 per cent above the average. Thus, under the conditions prevailing in this area, the greater the degree of diversity the higher the labor income until the diversity reaches about the equivalent of 4 to 5 equal enterprises. Beyond this there is a slight decrease in profits. The largest number of farms falls in the class where the profits are largest, so that on the whole the farmers of this locality practice a degree of diversified farming suited to their conditions. There appears to be little or no relation between the diversity of the farm business and size of farm, there being little difference in the average size of the farms in each of the classes of Table XLVII.

Essentially the same thing is shown by the data given in Table XLVIII. Here the same farms are classified by the proportion of income received from the sale of crop products. As in the previous table, there is here very little relation between size of farm and degree of diversity as indicated by percentage of receipts from crops. There is, however, a distinct relation between crop sales and profit as indicated by labor income.

TABLE XLVIII.—*Relation of per cent of income from crops to labor income, 378 Pennsylvania owners.*

Per cent of total income from crops.	Number of farms.	Average size of farms.	Average labor income.	Average adjusted income.
		<i>Acres.</i>		<i>Per cent.</i>
0 to 9.....	19	86	\$718	93
10 to 19.....	35	81	807	117
20 to 29.....	84	86	804	104
30 to 39.....	85	95	884	114
40 to 49.....	70	92	793	94
50 to 59.....	45	90	732	84
60 and over.....	40	92	629	83
Total or average.....	378	90	789	100

Those farms deriving from 10 to 39 per cent of their income from the sale of crops make considerably higher labor incomes than those deriving either more or less of their incomes from this source. There appears to be considerable latitude in this matter, since three of the

seven groups are all above the average in labor income. Undoubtedly, a good deal depends on the quality of the live stock kept. A farm having a large herd of cows of very high quality could probably afford to ignore the matter of diversity of business to a much greater extent than one having a herd of medium quality. In other words, quality of business may, within limits, compensate for lack of diversity of business.

THE STANDARD ROTATION.

We have already seen that as early as the latter part of the eighteenth century there began to be practiced in Chester County a crop rotation consisting essentially of corn the first year after sod; flax, oats, and barley the second year; wheat the third year, followed by grass, usually clover or clover and timothy. This rotation is said to have become quite general as early as 1820. Essentially the same rotation is described as being common in 1853. This general form of rotation persists to-day, and is quite commonly practiced, though with some modifications. The more usual form of it as now practiced is: First year, corn; second year, part corn, part potatoes, and part oats or a combination of any two of these; third year, wheat; fourth and fifth years, hay, usually clover and timothy. Some farmers omit potatoes, some the oats (replacing them usually by corn), while there is considerable variation in the length of time the meadow is maintained before plowing it up for corn again. In previous tables the acreage of these crops has been given in percentage of the entire crop area on the farm, including miscellaneous field crops and orchards. In Table XLIX the percentages are reduced to the basis of the crops mentioned.

TABLE XLIX.—*The standard rotation.*

Year.	Crop.	Average acreage on 378 farms. ^a	Suggested rotations.				
			5-year.		6-year.		
		<i>Per cent.</i>		<i>Per cent.</i>	<i>Year.</i>		<i>Per cent.</i>
First.....	Corn.....	20.0	Corn.....	20	First.....	Corn.....	16 $\frac{2}{3}$
Second.....	(Corn.....	3.0	Corn.....	14	Second....	Corn.....	16 $\frac{2}{3}$
	(Potatoes... 6.2						
	(Oats..... 6.6						
Third.....	Wheat....	18.8	Wheat....	20	Third.....	(Potatoes..	6
						Annual	10 $\frac{2}{3}$
						hay crop	
Fourth and fifth ^b	Hay.....	45.4	Hay.....	40	Fourth....	Wheat....	16 $\frac{2}{3}$
					Fifth and sixth....	Hay.....	33 $\frac{1}{3}$

^a Counting only the crops mentioned in this table.

^b Sometimes sixth also.

The third column of this table gives the actual average acreage of all these crops as found on the 378 owner farms (in percentage). It is seen that they represent very nearly the rotation outlined above. In the next column is given what the data obtained in this survey would indicate to be a somewhat better form of this rotation for the average farm in this region. We have seen (Table X) that the acreage of corn might be increased to advantage. We have also seen that oats are not profitable here. In this rotation the oat crop is replaced by corn. Many farmers, especially those who have silos, have already made this change, and in general their profits are considerably above the average for the region. But this form of rotation, while it is an improvement over the old, does not entirely meet the requirements of the most profitable system as indicated by the results of this survey. The area of wheat is a little too large, while that of hay is somewhat smaller than it should be for best results under average local conditions. It is also difficult to sow so large an area of wheat after corn unless the corn is cut for silage. The soil can not be put in proper condition, the sowing is frequently late, and the land is not left in the best of condition for the succeeding hay crops.

The 6-year rotation outlined in the last portion of Table XLIX appears to meet exactly the condition for greatest profit under average farm conditions in this region. It gives $33\frac{1}{3}$ per cent of corn acreage, which is within the limits indicated to be the most profitable by the data given in Table X. It gives $16\frac{2}{3}$ per cent of wheat acreage, which is almost the same as the present community average, and which, as we have already seen, is within the limits of the most profitable acreage for this crop in this locality. It gives 44 per cent of hay acreage, which is exactly equal to the present average, and which is also within the limits indicated to be most profitable for hay under average conditions in this region. The per cent of potato acreage is the same as the present average.

The annual hay crop occurring in the third year of this rotation presents somewhat of a problem. There are several possibilities to be considered. Oats might occupy this place. They can be cut for hay in the milk stage and make hay of very good quality.

Another possibility is oats and Canadian field peas, though this region is somewhat too far south for success with this combination unless the planting is done very early. Cowpeas, another possibility, are not adapted to heavy soils this far north.

Everything considered, the authors are of opinion that after the farmers have learned the management of the crop, soy beans would be decidedly the best annual crop in this 6-year rotation. It is much more dependable than cowpeas. The hay is rich in nitrogen and would thus considerably reduce the amount of concentrated feed

necessary; in fact, with a good crop of soy-bean hay and the additional corn which this rotation would give it would be possible to feed good rations to a large dairy herd with little or no purchase of concentrates. This should considerably reduce the expense of farming here.

It is realized that it is a serious matter to recommend the introduction of a crop that is new to most of the farmers of a region for so important a place in the cropping system as the annual hay crop in this 6-year rotation occupies. This objection holds particularly in the case of soy beans, because of the difficulty of making a success with them in regions where they have not been commonly grown before. The soy bean is a comparatively recent introduction into American agriculture. It is a legume, and the bacteria which it absolutely requires are not generally found in American soils. For this reason nearly every farmer who tries soy beans for the first time makes a failure of them. In view of this fact, the authors recommend that those who try this 6-year rotation use oats or cowpeas for the annual hay crop at first, but it is also recommended that the farmers of this locality begin generally to experiment with a small area of soy beans. This area should be located in some out-of-the-way place, and the first seeding of soy beans should be thoroughly inoculated with the bacteria which this crop requires. The bacteria may be obtained from the United States Department of Agriculture. Another way of inoculating is to get a quantity of soil from a field which has recently grown a good crop of soy beans. The inoculation by this method usually requires from 300 to 500 pounds of soil per acre. This should be done just before seeding. In distributing this inoculated soil, care should be used to avoid the direct rays of the sun, which tend to kill the bacteria. The inoculation should be done on either a cloudy day or late in the afternoon, and the soil should be harrowed at once in order that some of the bacteria may be covered up and thus protected from the light of the sun. Several farmers in Chester County have grown soy beans. A picture of such a field is shown in figure 10.

The first seeding of soy beans is often a failure, but the land will at least get a partial inoculation. The crop should be sown again on the same land the next year, and if necessary, again the third year. Certainly the third year a magnificent crop of soy beans should be obtained. This will supply seed sufficient for sowing the larger acreage in the rotation. Not only that, but the inoculated patch will supply ample soil with which to inoculate the field in which the soy beans are to be sown. The authors believe that when the soy-bean crop has become thoroughly established, and the details of its management are thoroughly understood by the local farmers, its use in the rotation here outlined will be found to add considerably to the profits in farming.

Every farmer who undertakes experiments with soy beans should send to the State experiment station and to the United States Department of Agriculture for the latest literature relating to this crop.

ALFALFA.

Thus far nothing has been said about alfalfa in this region excepting merely to mention the fact that some 75 acres of it were found upon the 378 owner farms. Since this survey was completed the area of this crop has considerably increased in Chester County. Where the cultivation of alfalfa is successful it is a desirable crop for live-stock farms, but the discussion of cropping systems involving alfalfa would lead into a field which is to be covered in another bulletin dealing with cropping systems for the region of this survey



FIG. 10.—Field of soy beans near West Chester, Pa., showing adaptability of this crop to local conditions in area of survey. (Photo by E. K. Hibschan.)

and other similar localities. It may be added, however, that on farms having a considerable acreage of alfalfa the 5-year rotation outlined in the middle of Table XLIX might be more satisfactory than the 6-year rotation. The alfalfa when once established should continue to occupy the same field as long as it is producing a satisfactory crop. The remainder of the farm could then be continued in the 5-year rotation.

FARM EXPENSES.

The data obtained in this survey are not sufficiently extensive to permit a detailed study of the relation between the expenditures for different purposes and the efficiency of local farming. It is not doubted, however, that such studies would give results of interest in connection with the problems of farm management. As records

of farm management surveys accumulate, these more detailed studies will become easily possible. For the present it must suffice to point out certain facts relating to farm expenses which may be useful in making comparisons between the farming of this region and that of other regions where different conditions prevail.

Table L shows the interesting fact that on all sizes of owner farms in the Chester County survey area the expense of conducting the farm business is from 39 to 47 per cent of the total farm receipts. There appears to be no particular relation between size of farm and the percentage of receipts required to meet expenses. There is an undoubted relation of this kind between type of farming and expenses, but since on the 378 owner farms there is little relation between type of farming and size of farm, this relation is not made evident in the tabulated data.

TABLE L.—*Proportion of receipts required for operating expenses.*

Size of farm (acres).....	13 to 40.	41 to 60.	61 to 80.	81 to 100.	101 to 120.	121 to 160.
Number of farms.....	54	61	60	68	52	61
Proportion of receipts required for operating expenses, etc.....	<i>Per cent.</i> 44.7	<i>Per cent.</i> 39.1	<i>Per cent.</i> 41.3	<i>Per cent.</i> 42.6	<i>Per cent.</i> 45.4	<i>Per cent.</i> 42.2

Size of farm (acres).....	Over 160.	All owners.	Tenant farms.	Tenant's share.	Landlord's share.	Specials.
Number of farms.....	22	378	124	124	124	27
Proportion of receipts required for operating expenses, etc.....	<i>Per cent.</i> 47.1	<i>Per cent.</i> 43.2	<i>Per cent.</i> 41.0	<i>Per cent.</i> 52.4	<i>Per cent.</i> 28.0	<i>Per cent.</i> 48.7

On the average for all the owners, current expenses amount to 43.2 per cent of the total receipts. On the 124 tenant farms it is a little less than this, being just 41 per cent. It appears that both tenant and landlord are somewhat more economical in the matter of expenditures than is the case with those who operate their own farms, which is to be expected. The owner who operates his own farm has not only a labor income, but interest on his capital as well with which to provide the family living. The tenant has little more than his labor income, while the landlord has only his income on capital. In the case of both landlord and tenant economy is thus more a matter of necessity than it is in the case of the owner operator.

While the total expense of landlord and tenant combined amounts to 41 per cent of the receipts on tenant farms (not counting rent), the data in Table L shows that the tenant expends 52.4 per cent and the landlord 28 per cent of his receipts in the conduct of the farm business. On the 27 special farms on which a hothouse business is

conducted, both receipts and the percentage of these receipts required to meet business expenses are larger than on farms of other types found in this survey, the expenses amounting to 48.7 per cent of the receipts.

Table LI shows in detail the nature and relative amount of expenditures for different purposes on owner farms of different sizes and on tenant and special farms. The data for tenant farms are given in the fourth column from the last in such manner as to include both tenants' and landlords' expenses, leaving out the rent paid by the tenant. In the third column from the last the average expenditures of the landlords for the entire number of tenant farms is given. The second column from the last gives the expenses of cash tenants, including rent. The last column gives the expenses of share tenants, not including rent. On owner and tenant farms the largest single item of expense is for hired labor, this item being slightly greater on owner than on tenant farms. The owner operator, having both labor and capital income, can afford to hire a greater proportion of his labor, although, on the average, owner farms are smaller than the tenant farms in this region.

TABLE LI.—*Distribution of farm expenses on owner, special, and tenant farms, Chester County.*

	Acres.						Over 160.	Total owner farms.	Special farms.	Total for tenant farms.	Landlord's expenses.	Cash-rent tenant.	Share-rent tenant.
	40 and less.	41 to 60.	61 to 80.	81 to 100.	101 to 120.	121 to 160.							
Number of farms....	54	61	60	68	52	61	22	378	27	124	124	53	71
Paid labor.....	<i>P. ct.</i> 13.0	<i>P. ct.</i> 15.4	<i>P. ct.</i> 24.4	<i>P. ct.</i> 28.5	<i>P. ct.</i> 24.6	<i>P. ct.</i> 30.7	<i>P. ct.</i> 36.1	<i>P. ct.</i> 26.8	<i>P. ct.</i> 37.4	<i>P. ct.</i> 23.5	<i>P. ct.</i> 1.2	<i>P. ct.</i> 19.3	<i>P. ct.</i> 35.0
Board, paid labor....	4.2	4.6	6.1	7.1	5.8	6.0	3.5	5.6	3.6	5.6	1.1	4.3	8.8
Family labor.....	16.4	16.2	10.1	7.7	12.9	6.9	5.0	9.6	4.1	9.4	1.5	6.4	15.1
Machinery repairs...	1.5	2.3	1.4	1.6	2.0	1.3	1.6	1.6	1.3	1.6	.7	1.2	2.0
Building repairs....	2.7	1.9	1.2	1.2	1.2	1.2	1	1.8	.7	1.8	3.6	1.8	.2
Fence repairs.....	1.4	1.1	.9	.8	1.4	.8	.7	1.0	1.0	1.3	4.3	.2	.2
Drain repairs.....	.....	.1	.....	.1	.....	.....	.....	.1	.....	.....	.1	.....	.....
Feed, silage, etc....	1.1	.7	1.1	.6	1.1	.6	1.7	.9	.1	.9	.8	1.1	.4
Feed, grain, etc....	24.7	19.0	18.1	17.5	19.7	16.0	21.3	18.7	7.6	22.0	26.7	18.4	16.1
Feed grinding.....	1.6	1.8	1.4	1.5	1.1	1.3	1.1	1.3	.3	1.5	1.8	1.1	1.4
Ice and milk haul...	.....	.....	.6	.....	1.0	.3	.....	.3	.0	.....	(a)	(a)	(a)
Horseshoeing.....	2.7	2.9	2.5	2.3	2.0	2.0	1.3	2.1	1.1	2.4	.9	1.8	3.2
Breeding fees, vet....	.9	.7	.8	.7	.7	.7	.8	.7	.9	.6	.9	.6	.6
Seeds, plants, etc...	3.9	5.8	4.3	5.1	3.4	4.5	3.6	4.3	2.2	3.9	6.8	2.6	2.5
Fertilizer.....	11.3	13.1	13.5	12.0	11.4	13.0	11.3	12.3	20.8	11.2	20.1	7.8	6.1
Spray material.....	.1	.1	.....	.1	.1	.....	.....	.1	.....	.1	.1	(a)	.1
Twine.....	.2	.4	.4	.4	.3	.4	.3	.4	.1	.4	.2	.3	.4
Thrashing.....	1.4	1.4	1.6	1.4	1.2	1.5	1.3	1.4	.4	1.4	1.4	.9	1.4
Pressing.....	1.0	1.7	2.0	1.8	1.8	2.5	2.1	2.0	.8	1.6	1.8	1.0	1.6
Machine hire.....	.5	.6	.3	.3	.3	.2	.....	.2	.1	.3	.1	.3	.2
Fuel, oil, barrels, etc.	.5	.6	.6	.7	.7	.7	.6	.7	6.6	.6	.5	.5	.7
Insurance.....	2.7	2.1	1.9	1.8	1.6	1.9	1.9	1.9	1.2	2.2	6.0	.7	.9
Taxes.....	8.0	7.3	6.8	6.7	5.8	7.4	5.6	6.7	3.3	7.3	20.2	2.5	2.9
Miscellaneous.....	.2	.2	.....	.1	.....	.1	.....	.1	.1	.2	.5	(a)	.2
Mushroom spawn.....	.....	.....	.....	.....	.....	.....	.....	.....	6.4	.....	.....	.....	.....
Cash rent.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	26.9	.....
Total.....	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

^a Less than one-tenth of 1 per cent.

The next largest item is for concentrated feedstuffs, in this case the expenditure being somewhat greater on tenant farms than on the others. We have already seen that these tenant farms are somewhat more heavily stocked with dairy cows than owner farms are.

The third most important item is for fertilizers, in this case the larger expenditure being made by owner operators. The slight difference in this item on the two classes of farms may be due in part to the larger number of cattle kept on the tenant farms.

The expenditure for hired labor increases materially with increase in size of farm. The smaller the farm the larger the proportion of the work the farm family is able to do. The only other item of expense which shows a noticeable increase on the larger farms is that for baling hay and straw ("pressing"). This is because of the fact that the larger farms sell a somewhat larger proportion of their hay. On the other hand, many of the items are seen to decrease in relative amount as the size of the farm increases. It is quite natural that the item of family labor should thus decrease, for reasons already stated. Expenditures for repairs of buildings and fences, for horseshoeing, insurance, and taxes decrease relatively as the size of farm increases because of the relatively larger proportion of capital invested in the items concerned on the smaller farms. Purchased feed decreases on the larger farms because of their ability to produce a larger proportion of the required feedstuffs.

The largest item in the expenses of the cash tenant is of course rent, which amounts to about 27 per cent of his total expenses. The only other considerable items are for labor, concentrated feeds, and fertilizers. These farms are considerably smaller than the farms of share tenants, and hence the expenditures for hired labor are smaller. The percentage of expenditures for labor on the cash tenant farms is reduced because of the fact that the rent is included in this column, and hence is not directly comparable with the figure in the last column of the table where the rent is not taken into account. If we omit the rent in next to the last column the figure for hired labor would be about 25 per cent, which is about what it should be in comparison with the expenditures of share tenants when the relative size of the two classes of farms is taken into consideration.

It is interesting to note that share tenants have relatively a very large amount of unpaid family labor. These are rather large farms. Amongst owners the only two groups of farms which have as large a percentage of family labor as the share tenants are the two groups of smallest farms.

On the special farms two items of expense overshadow all others. They are for labor and for the horse manure which is the basis of the hothouse business as here conducted.

FEEDING STUFFS.

On the whole, the farmers of Chester County grow a larger quantity of feedstuffs than they feed. They produce a large excess of hay, the majority of farms selling some of this product. A considerable number of farms grow more corn than is needed on the farm and an occasional farmer sells some oats. The average value of farm feed sold per animal unit was \$21.08 (see Table LIII). At the same time these farmers bought on an average \$10.11 worth of feed per animal unit, mostly in the form of grain and mill stuffs. They thus produce an excess of roughage and a deficit of concentrates. This is the usual situation on farms devoted largely to live stock. In this region nearly every farmer who keeps any considerable number of live stock buys concentrates. The number who sell roughage, principally hay, is less. Some farms sell a large quantity of hay, while others that are more heavily stocked sell little or none. Whether it pays to sell hay depends on the situation on the individual farm. If the dairy cows are of the best quality it would probably pay best to keep enough of them to consume all the roughage grown, buying enough concentrates to make up any deficiency in the quantity produced. Where the cows are of only moderate quality it is undoubtedly good practice to sell some hay. We have already seen that on the average those farmers who sell a small quantity of hay make higher profits than those who sell none or a large quantity. This is probably due to the fact that the average dairy cow in this region is only moderately good. If all were as good as the best, it would, in all probability, pay to increase their number and feed all the hay.

TABLE LII.—*Feed cost per animal unit on 378 farms operated by owners, Chester County.*

Kind of feed.	Amount raised.	Amount sold.	Amount consumed.	Price.	Value of feed consumed.
Corn for grain and other purposes.....	<i>Bushels.</i> 265,313	<i>Bushels.</i> 25,788	<i>Bushels.</i> 239,525	\$.75	\$179,644
Silage.....	<i>Tons.</i> 6,678	<i>Tons.</i> 6,678	<i>Tons.</i> 6,678	4.00	26,712
Hay.....	<i>Bushels.</i> 12,481	<i>Bushels.</i> 5,642	<i>Bushels.</i> 6,839	18.00	123,102
Oats.....	<i>Bushels.</i> 54,360	<i>Bushels.</i> 2,725	<i>Bushels.</i> 51,635	.50	25,818
Rye.....	<i>Bushels.</i> 224	<i>Bushels.</i> 52	<i>Bushels.</i> 172	.80	138
Barley.....	<i>Bushels.</i> 229	<i>Bushels.</i> 229	<i>Bushels.</i> 229	.75	172
Oats and speltz.....	<i>Bushels.</i> 160	<i>Bushels.</i> 160	<i>Bushels.</i> 160	.60	96
Straw ^a	<i>Tons.</i> 5,000	<i>Tons.</i> 900	<i>Tons.</i> 4,100	4.00	16,400
Stover ^a	<i>Tons.</i> 6,000	<i>Tons.</i> 6,000	<i>Tons.</i> 6,000	5.00	30,000

^a Yield estimated.

Total value of farm feed.....	\$402,082.00
Increase in inventory value.....	36,061.00
Total value of farm feed consumed.....	366,021.00
Total value of farm feed consumed per animal unit.....	49.79
Value of feed purchased.....	74,304.00
Value of feed purchased per animal unit.....	10.11
Total feed cost.....	440,325.00
Total feed cost per animal unit.....	59.90

Table LII gives the facts concerning feedstuffs raised, fed, sold, and purchased. Almost exactly one-tenth of the total corn produced for grain was sold, the remaining nine-tenths being fed. A much larger proportion of the oats produced was consumed on the home farm. The total value of feedstuffs produced on these 378 farms and not sold, valued at average farm prices, which are somewhat less than market prices, was \$402,082. Of this, \$36,061 represented an increase in inventory over the previous year, and was hence not fed during the year to which this study relates. This leaves a total of \$366,021 worth of feedstuffs produced and fed on these farms during the year, or \$49.79 worth per animal unit.

Adding to this the \$10.11 worth of feed bought, we have a total value of feed per animal unit of \$59.90. The actual commercial value of the feedstuffs used on these farms is thus in the neighborhood of \$60 per animal unit. The corresponding income was \$84.90, a difference of about \$25.

The above figures include all kinds of animals kept on these farms except that in determining income per animal unit the work horses were left out of consideration. It does not follow from these figures that the farmers would have made more profit if they had had no live stock. In the first place, the stock furnishes a very good market for much of the crop products of the farm. Had it not been for the live stock on these and other farms in this region this market with present prices would not have existed. In the second place, the presence of the animals permits a diversification of crops which in itself distributes the labor throughout the summer and part of the winter and thus enables the farmer to do a larger proportion of his work instead of hiring it done. In the third place, the live stock furnishes directly a large amount of employment at times of the year which would otherwise remain unoccupied. We shall also see later that the manure produced by the live stock on Chester County farms has a very decided money value, by reason of the increased yield of crops resulting from its use. This value is about \$15 per animal unit. This, together with the excess of income over feed value, gives about \$40 per animal unit as reward for labor, shelter, up-keep of equipment, etc., made necessary by the presence of the live stock. Except in the case of poultry and dairy cows, the amount of labor required in caring for farm animals is comparatively small. On the whole, therefore, the live stock in this region appears at least to be paying its way, and the fact that it furnishes the farmer with a large amount of productive labor and at the same time pays a fair price for what feed is consumed fully justifies the types of farming which prevail. Without this live stock these farmers would have

been idle a large portion of the year and would have made proportionately smaller incomes.

The classes of feed crops grown and their relative acreage are shown in Table LIII. On the average for all the farms there are grown, for each animal unit kept, corn, 0.62 acre; small grain for feed, 0.18 acre; and hay, 1.23 acres; a total of 2.03 acres of feedable crops per animal unit. In addition to this we have 1.18 acres of pasture per animal unit, a total of 3.21 acres of land devoted to pasture and feedable crops per animal unit.

TABLE LIII.—*Acres of feedable crops and pasture per animal unit on 378 owner farms, Chester County.*

Acreage of farms.....	{ 40 or less.	41 to 60.	61 to 80.	81 to 100.	101 to 120.	121 to 160.	Over 160.	All farms.
Number of farms.....	54	61	60	68	52	61	22	378
Number of animal units per farm.....	7.6	12.5	16.6	20.2	24.4	26.7	41.8	19.4
Per animal unit.								
Corn for grain.....	}	0.60	0.59	0.60	0.62	0.63	0.62	0.62
Corn for silage.....								
Other corn.....								
Oats and other grains for feed.....		.13	.14	.18	.20	.17	.19	.18
All hay.....		.99	1.05	1.22	1.26	1.15	1.40	1.23
Total feed crops.....		1.72	1.78	2.00	2.08	1.95	2.21	2.03
Pasture ^a		.88	1.08	1.10	1.08	1.23	1.27	1.18
Grand total.....		2.60	2.86	3.10	3.16	3.18	3.48	3.21
Value of farm feeds sold.....		\$13.43	\$15.27	\$20.55	\$20.80	\$17.93	\$25.41	\$30.25
Value of feed purchased.....		12.75	8.85	9.61	9.36	11.10	8.34	13.37

^a Does not include work horses.

The last two lines of this table show that a considerable proportion of the feedable crops are sold, the amount realized therefrom being considerably greater than the amount expended for feedstuffs bought.

PRODUCTION AND UTILIZATION OF SILAGE.

Of the 378 owners operating their own farms, 56 had silos (see Table LIV). Silage is fed an average of 203 days during the year, or about 6 $\frac{2}{3}$ months. The average amount fed per day, as estimated by 24 of the farmers feeding this material, was 40 pounds per cow. Estimates of the amount fed per day are presumably based on occasional weighings of the feed given. But in estimating the amount of silage stored on the farm it is customary to base estimates on silo capacity as given by King's rules. The farmers' estimates of the amount of silage stored by them amount to 46 pounds per head per day for the usual feeding period, a difference of 13.1 per cent of the amount stored. If both these estimates are approximately correct, they indicate an average loss of silage stored amounting to 13 per cent.

TABLE LIV.—Amount of silage raised and fed per head of cattle on owner farms, Chester County.

Number of cattle.	Number of farms.	Average number of cattle units. ^a	Average number of days feeding silage. ^b	Average amount fed per day per head. ^b	Average amount raised for feed per day per head. ^b	Number of tons fed per year per head.	Number of tons raised for feed per year per head.	Loss.
				<i>Pounds.</i>	<i>Pounds.</i>			<i>P. ct.</i>
1 to 14.....	5	9	200	38	53	3.80	5.30	28.3
15 to 24.....	26	20	192	43	45	4.13	4.32	4.4
25 to 34.....	16	29	224	32	36	3.58	4.03	11.2
35 and over.....	9	50	212	45	50	4.77	5.30	10.0
Total.....	56	26	203	40	46	4.06	4.67	13.1

^a Figured on basis that 2 head of young stock = 1 cow, bull, or steer.^b Answers by letter from 24 farmers.

On account of the manner in which this estimate was obtained, the figures here given can only be considered a first approximation at this loss. It should be stated, however, that this estimated loss of 13 per cent is in close agreement with the rather meager chemical investigations of the subject.¹

It is worthy of note that the largest losses occur on those farms feeding the smallest number of cattle. Unless there are cattle enough to consume the entire surface layer of silage to a depth of several inches daily, there is a good deal of loss from decay of silage left too long in contact with the air.

The average number of tons of silage stored per head of stock to be fed is seen by Table LIV to be $4\frac{2}{3}$. The actual amount fed appears to be about 4 tons per head in $6\frac{2}{3}$ months. The common practice here is to feed silage during the winter, and during periods of the summer when pastures are short.

RATE OF DEPRECIATION OF DAIRY COWS.

The data obtained in this survey make it possible to calculate the rate of depreciation on dairy cows, as well as on farm horses. The rate thus obtained does not, however, represent the annual rate at which an animal deteriorates after it passes its prime, for as the calculation is here made the depreciation of such animals is in part cancelled by the increase in value of animals before they reach their prime. But the rate here obtained does represent approximately the average charge which must be made for depreciation in determining the cost of maintaining the dairy herd. The method of calculation is shown in detail in Table LV. This method may be applied to an individual herd of cows, as well as to the average of a large number of herds.

¹ See Henry's Feeds and Feeding, edition of 1898, p. 246, where this loss is given as 10.8 to 20.0 per cent.

TABLE LV.—*Showing depreciation of dairy cows on 378 farms operated by owners, Chester County.*

	Number.	Value per head.	Total value.
First inventory.....	4,196	\$56.10	\$235,400.00
Cows purchased.....	589	63.84	37,605.00
Cows raised.....	345	63.84	22,025.00
Total.....			295,030.00
Second inventory.....	4,164	57.01	237,430.00
Cows sold and slaughtered.....	895	37.36	33,437.00
Total.....			270,867.00
Difference.....			24,163.00
Increase at end of year in value.....		.91	3,789.00
Total loss.....			27,952.00
Average investment.....			236,415.00
Rate of depreciation..... per cent.			11.82

The results of the calculation are somewhat surprising, and the figures for different regions vary widely. Thus for the Chester County area the average annual loss on dairy cows from depreciation in value is 11.82 per cent of the average of the inventory values for the beginning and the end of the year. Table LVI gives a similar calculation for a survey in an important dairy center in southern Michigan (Lenawee County), in which the corresponding rate is only 4.07 per cent. The reason for this remarkable difference will be made clear shortly.

TABLE LVI.—*Showing depreciation of dairy cows on 300 farms, Lenawee County, Mich.*

	Number.	Value per head.	Total value.
First inventory.....	2,291	\$53.23	\$121,942.00
Cows purchased.....	184	48.48	8,921.00
Cows raised.....	236	48.48	11,441.00
Total.....			142,304.00
Second inventory.....	2,215	51.90	114,967.00
Cows sold and slaughtered.....	466	42.00	19,572.00
Total.....			134,539.00
Loss (including decrease in value at end of year).....			7,765.00
Decrease in value at end of year.....		1.33	2,946.00
Total loss.....			4,819.00
Average investment.....			118,454.00
Rate of depreciation..... per cent.			4.07

In making these calculations it is assumed that it costs as much on the average to raise a dairy cow as the average price at which cows are purchased in the respective localities. This may be in error, but even if the cost is considerably less the results would not vary greatly from those given, because of the relatively small proportion of cows raised, especially in the Pennsylvania area.

The remarkable difference in the rate of depreciation of dairy cows in Chester County, Pa., and in Lenawee County, Mich., is due mainly to the difference in the prices at which cows are bought and sold in the two localities. In the Michigan locality the average price paid for cows by dairy farmers was \$48.48. The average price at which these same farmers sold their discarded cows was \$42, a difference of only \$6.48. In the Pennsylvania locality the average purchase price was \$63.84, while the average sale price was \$37.36, a difference of \$26.48. The Pennsylvania farmer thus loses \$20 more per cow bought and sold than does the Michigan farmer. This accounts for the much larger annual charge for depreciation on the Pennsylvania farms.

In the Chester County area the farmers on the average raise 37 per cent of their cows and buy the remainder. In the Michigan locality they raise 57 per cent. The proportion of the average herd discarded yearly is 23 per cent in Pennsylvania and 21.6 per cent in Michigan. The average length of time the average cow remains in these herds is therefore 4.34 years ($=100/23$) in the Pennsylvania area and 4.52 years in the Michigan area. The yearly percentage of deaths in the herds was 1.69 for Pennsylvania and 1.31 for Michigan.

In the above calculations it is assumed that the few cows butchered were worth on the average as much per head as those sold. As very few were butchered, whatever error there may be in this assumption is of minor importance.

DEPRECIATION OF FARM WORK HORSES.

The rate of depreciation of farm work horses in these same localities is shown by the calculations given in Tables LVII and LVIII. In both cases the annual rate is very close to 5 per cent. This does not represent the rate at which a horse depreciates after he has passed his prime, since, as in the case of dairy cows, this depreciation is partly offset by the increase in value of young horses.

TABLE LVII.—Showing depreciation of horses on 378 farms operated by owners, Chester County.

	Number.	Value per head.	Total value.
Value at first inventory.....	1,369	\$135.98	\$186,183.00
Value of horses purchased.....	103	157.36	16,208.00
Value of horses raised.....	8	157.36	1,259.00
Total.....			203,650.00
Value at second inventory.....	1,367	138.95	189,947.00
Value of horses sold.....	64	128.02	8,193.00
Total.....			198,140.00
Loss.....			5,510.00
Increase in price during year.....		2.97	4,060.00
Total loss.....			9,570.00
Average investment.....			188,065.00
Rate of depreciation..... per cent.			5.09

The rate is largely determined by the practice of farmers in disposing of horses while they are still salable at a fairly satisfactory price. If all farm horses were kept until their usefulness was at an end, the depreciation on them would undoubtedly be much greater than the results here found. The death rate would also be much greater. As it is, the percentage of deaths among the farm horses in the Pennsylvania area was 3.58 per cent annually, and in the Michigan area 3.31 per cent. This is not the average annual death rate among horses generally; if it were, it would indicate an average lifetime of nearly 30 years. But it is the average annual death rate of horses during the period they are kept on these farms.

On the average, the farmers of the Michigan locality keep a horse 8.5 years, and sell him then for \$18.68 less than they paid for him. The Pennsylvania farmer, on the other hand, keeps his horses an average of 12.1 years, and then sells them for \$29.34 less than they cost originally.

TABLE LVIII.—*Table showing depreciation of horses on 300 owner farms, Lewanee County, Mich.*

	Total number.	Value per head.	Total value.
Horses at beginning of year ^a	1,027	\$126.50	\$129,912.00
Horses purchased.....	90	161.31	14,518.00
Horses raised.....	37	161.31	5,968.00
Total.....			150,398.00
Horses at end of year.....	1,033	132.91	137,299.00
Horses sold.....	87	142.63	12,409.00
Total.....			149,708.00
Loss.....			690.00
Increase in price during year.....		6.41	6,621.00
Total loss.....			7,311.00
Average investment.....			150,053.00
Rate of depreciation.....			4.87

^a Does not include 3 stallions valued at \$1,100 apiece.

VALUE OF FARM MANURE PER ANIMAL UNIT.

The data obtained in the usual farm-management survey make it possible to estimate at least roughly the money value of the manure of farm animals on the basis of the actual increase in crops yield on farms having large complements of live stock as compared with those having few animals. The results obtained by the method outlined in Tables LIX and LX will depend on the character of the soil, the character of the crops grown, the value of these crops per unit of product, and on the methods practiced by farmers in the management of manure.

TABLE LIX.—*Value of manure per animal unit determined by comparing two groups of Chester County farms.*

[The first group contains 94 farms (one-fourth of entire number) having the least number of animal units per 100 acres of crops (average, 20.36). The second group includes 94 farms having the highest number of animal units per 100 acres of crops (average, 56.85). Difference, 36.49 animal units.]

Crops.	Acres per 100 acres of crop. ^a	Average yield per acre.		Increase in yield per acre	Increase in production per 100 acres of crops.	Prices. ^a	Value of increased production, per 100 acres of crops.
		Lowest group of 94 farms.	Highest group of 94 farms.				
Corn.....	23	<i>Bushels.</i> 59.98	<i>Bushels.</i> 71.83	<i>Bushels.</i> 11.85	<i>Bushels.</i> 272.55	\$0.80	\$218.04
Potatoes.....	6.21	79.18	83.09	3.91	24.24	1.04	25.21
Wheat.....	18.8	23.90	25.56	1.66	31.21	.92	28.71
Oats.....	6.6	37.86	43.67	5.81	38.35	.55	21.09
		<i>Tons.</i>	<i>Tons.</i>	<i>Tons.</i>	<i>Tons.</i>		
Hay.....	45.4	1.22	1.55	.33	14.98	22.12	331.36
Total.....							624.41

Excess of fertilizer used by second group, per 100 acres of all crops..... 48.00
 Increase due to 36.49 animal units..... 576.41
 Increase due to one animal unit..... 15.80

^a Areas and prices are the averages for the entire 378 farms operated by their owners. These are used in order to eliminate factors other than the quantity of manure available. The crop areas given here are per 100 acres of the five crops mentioned.

The figures given for the value of manure per animal unit represent merely the increase in crop values due to the use actually made of the manure on the farms in question. The cost of caring for the manure and of spreading it on the fields must be deducted from these figures. The average cost of spreading manure on the fields is about 50 cents per ton, or about \$5 or \$6 per animal unit. It must be remembered, however, that most of this cost is represented by labor which the farmer may perform himself, and that whatever he gets for his labor is added to his annual income, even if it be less than ordinary wages.

In making these calculations the farms of each locality were divided into four equal classes, based on the number of animal units kept per hundred acres of crops. The calculations relate only to the major field crops, but the figures are handled in such a manner as to credit similar average increases in yield and acre value to minor field crops and to orchard lands.

No account has been taken of whatever manure may have been used on kitchen gardens or on permanent pasture land. There should undoubtedly be some credit for these two classes of land, but as there is no way of arriving at its value no account could be taken of it in these calculations. Studies are now in progress with a view to determining the value of manure used on pasture lands in this and other localities.

TABLE LX.—*Value of manure per animal unit determined by comparing two groups of Lenawee County (Mich.) farms.*

[The first group includes 75 farms (one-fourth of the entire number) having the least number of animals per 100 acres of crops (average, 19.44). The second group includes 75 farms (one-fourth of entire number) having the largest number of animals per 100 acres of crops (average, 48.53). Difference, 29.09.]

Crops.	Acres per 100 acres of crops. ^a	Average yield per acre.		Increase in yield per acre.	Increase in production per 100 acres of crops.	Prices. ^a	Value of increased production per 100 acres of crops.
		Lowest group of 75 farms.	Highest group of 75 farms.				
Corn.....	29.8	<i>Bushels.</i> 51.63	<i>Bushels.</i> 56.00	<i>Bushels.</i> 4.37	<i>Bushels.</i> 130.23	\$0.63	\$82.04
Potatoes.....	.7	73.29	85.07	11.78	8.25	.83	6.85
Wheat.....	15.9	20.84	23.54	2.70	42.93	.98	42.07
Oats.....	18.4	38.77	44.43	5.66	104.14	.46	47.90
Barley.....	2.0	24.79	25.76	.97	1.94	1.00	1.94
Hay.....	33.2	<i>Tons.</i> 1.08	<i>Tons.</i> 1.18	<i>Tons.</i> .10	<i>Tons.</i> 3.32	18.50	61.42
Total.....							242.22

Excess of fertilizer used by the second group per 100 acres of crops..... 3.00

Increase due to 29.09 animal units..... 239.22

Increase due to one animal unit..... 8.22

^a Areas and prices are the averages for the entire 300 farms operated by their owners. These are used in order to eliminate factors other than the quantity of manure available. The crop areas given here are per 100 acres of six crops mentioned.

The comparison on which the estimates of value are made is between the fourth of the farms having the fewest animal units per hundred acres of crops and the fourth having the highest number. The farms having most live stock in general had larger acreage of corn than did those with less live stock. As a large part of the increase in crop values per acre was due to the marked increase in the yield of this crop, the actual crop values on the more heavily stocked farms were somewhat greater than the figures given in the tables indicate. But this was due to the greater acreage of the more profitable crop, and not to greater yield per acre. In order, therefore, to ascertain the actual effect due to manure alone it was necessary to use the average acreage of each crop on the entire number of farms. This gives the same relative acreage of each crop on the farms in each group. The prices used are also the average for all the farms, for such differences in prices as occurred on the groups of farms compared were not due to the effect of the manure.

In the Pennsylvania area the increase in crop values due entirely to increase in yields on the more heavily stocked farms is seen to amount to \$15.80 per animal unit per year. In the Michigan area the corresponding figure is \$8.22. The soils of the Pennsylvania area are in the main of granitic origin, and are more in need of fertilization than those of the Michigan area, which are of glacial origin and contain more lime and soluble mineral matter. Manure

being more valuable to the Pennsylvania farmer, he takes better care of it than does his Michigan competitor.

These figures are at best a mere first approximation to an important result. The method here used is entirely new, and may have defects which the authors have overlooked. Its importance, however, appears to justify its publication as a means of stimulating research along this line.

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A. D. MELVIN, Chief



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PROFESSIONAL PAPER

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THE PRESENT STATUS OF THE PASTEURIZATION OF MILK.

By S. HENRY AYERS, *Bacteriologist, Dairy Division.*

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MEANING OF THE TERM "PASTEURIZATION."

The term "pasteurization," as applied to milk, should mean a process of heating to 145° F. and holding at that temperature for 30 minutes, but as applied under commercial conditions it is the process of heating for a short or long period, as the different methods demand, at temperatures usually between 140° and 185° F. The process is followed by rapid cooling. The term originated from the experiments of Louis Pasteur in France. From 1860 to 1864, in experimenting on the "diseases" of wine, he found that heating for a few moments at temperatures of from 122° to 140° F. was sufficient to prevent abnormal fermentations and souring in the wine. A little later he found that by a similar heating beer could be preserved from souring. The application of the process gave rise to the term "pasteurization."

VALUE OF PASTEURIZATION.

From a sanitary standpoint the value of pasteurization is of the greatest importance when market milk is under consideration. The

NOTE.—This bulletin will be of interest to health officers, medical men, scientific dairy-men, and others who may be interested in the subject of pasteurization.

pasteurization of milk, when the process is properly performed, affords protection from pathogenic organisms. Such disease-producing bacteria as *Bacillus tuberculosis*, *B. typhi*, *B. diphtheriae*, and the dysentery bacillus, when heated at 140° F. for 20 minutes or more, are destroyed, or at least lose their ability to produce disease.

According to Mohler (1),¹ pasteurization offers protection against foot-and-mouth disease. He makes the following statement: "Milk which has been pasteurized for the elimination of tubercle and typhoid bacilli will not prove capable of transmitting the disease [foot-and-mouth] to persons or animals fed with it." In view of the recent outbreak of foot-and-mouth disease in this country this is of importance.

Within recent years several epidemics of septic sore throat have been traced to milk. In some of these epidemics it was found possible by pasteurization to destroy streptococci which were isolated from throats of infected people and which were believed to be the infective agents. Pasteurization, properly performed, seems to protect against epidemics of this kind, but until the organism which causes the disease is definitely known it is impossible to say that it affords absolute protection.

Epidemics of scarlet fever have been traced to milk supplies, and in such cases pasteurization has been resorted to, with apparently satisfactory results, as a means of safeguarding the public health.

Pasteurization is of value from a commercial standpoint so far as it increases the keeping quality of the milk and prevents financial losses by souring. As practiced at the present time, commercial pasteurization, with reasonable care, destroys about 99 per cent of the bacteria, and while it does not prevent the ultimate souring of milk, it does delay the process. At the present time pasteurization is the best process for the destruction of bacteria in milk on a commercial scale. Many attempts have been made to destroy these bacteria by means of electricity, but its use commercially has not proved satisfactory. Its action is usually indirect, the bacteria being destroyed through the heat produced by the electric current or through chemical substances produced by decomposition of the milk. It is possible, however, that future research will develop some satisfactory method of treating milk in this manner.

The use of ultra-violet rays for the destruction of bacteria in milk has not proved to be of value as a commercial process. Experiments with these rays carried on by Ayers and Johnson (2) showed that while the rays cause great destruction of bacteria in milk, when exposed under suitable conditions, the process in its present state

¹ See references to literature at end of paper.

of development can not replace that of pasteurization on a commercial scale.

EXTENT OF PASTEURIZATION IN THE UNITED STATES.

Pasteurization, when first practiced by milk dealers in this country, was carried on secretly, and, except as a means of preserving the milk, was regarded by them as a process of no value. As the practice became more general the subject of pasteurization was studied, and its value as a means of destroying disease-producing bacteria was recognized. In consequence of the recognition of the merits of the process there has been during the last 10 years a rapid increase in the quantity of milk pasteurized, particularly in the larger cities. Jordan (3) states that 10 years ago only about 5 per cent of the milk supply of New York City was pasteurized, as compared with about 40 per cent in 1912 and 88 per cent in 1914. In Boston, in 1902, very little milk was pasteurized, while at present 80 per cent is so treated, and in many of the smaller cities there have been corresponding increases in the quantity of milk pasteurized during the last few years.

The general tendency in this country to-day is toward the pasteurization of all market milk, with the exception of certified and inspected milk from tuberculin-tested herds. Some idea of the extent of pasteurization may be gained from Table I. The figures¹ were supplied by the milk-investigations section of the Dairy Division and were obtained from replies to circular letters sent to health officers.

TABLE I.—*Extent of pasteurization of milk in cities in the United States.*

Population of cities.	Number of cities answering question.	More than 50 per cent pasteurized.	11 to 50 per cent pasteurized.	0 to 10 per cent pasteurized.	None pasteurized.
More than 500,000.....	9	7	2	0	0
100,001 to 500,000.....	40	12	20	6	2
75,001 to 100,000.....	19	5	8	4	2
50,001 to 75,000.....	30	4	15	6	5
25,001 to 50,000.....	78	13	31	12	22
10,001 to 25,000.....	168	10	40	18	100
Total.....	344	51	116	46	131

It will be seen that of nine cities with a population of more than 500,000 each, in seven more than 50 per cent of the milk is pasteurized; in fact, the proportion is much higher, as Table II shows. Since these figures were obtained the per cent of milk pasteurized has probably increased in these cities.

¹ These figures were obtained through the kindness of Mr. Ernest Kelly and Mr. L. B. Cook.

TABLE II.—*Proportion of total milk supply pasteurized in certain cities.*¹

City.	Per cent pasteurized.	City.	Per cent pasteur- ized.
Boston, Mass.....	80	Philadelphia, Pa.....	85
Chicago, Ill.....	80	Pittsburgh, Pa.....	99
Detroit, Mich.....	57	St. Louis, Mo.....	70
New York, N. Y.....	88		

¹ In the small cities the per cent of milk pasteurized is much lower.

METHODS OF PASTEURIZATION.

At present there are three processes of pasteurization practiced in this country. The first is known as the flash, or continuous, process; the second, the holder, or holding, process; and the third is known as pasteurization in the bottle.

The flash process consists in heating rapidly to the pasteurizing temperature, then cooling quickly. In this process the milk is heated from 30 seconds to 1 minute only, usually at a temperature of 160° F. or above.

In the holder process the milk is heated rapidly to temperatures of from 140° to 150° F. and held for approximately 30 minutes, after which it is rapidly cooled. Sometimes the milk, instead of being held at a certain temperature in one tank for 30 minutes, is merely retarded in its passage through several tanks so that the length of time is required for the milk to pass through. In such cases, however, there is no assurance that all the milk is held for the desired time. The holder process, which is gradually replacing the flash process, is more effective and is superior in every way.

Pasteurization in bottles is the latest development of the process to be used on a practical scale. This process, as first practiced, consisted in putting the raw milk into bottles with water-tight seal caps, then immersing them in hot water until heated to 145° F. and holding them at that temperature for 20 or 30 minutes. The cooling was accomplished by gradually lowering the temperature of the water until that of the milk reached 50° F. This method is now in use in several milk plants. The advantage of this process is in the fact that the milk after heating is not exposed until it reaches the consumer, thereby eliminating any danger of reinfection with disease-producing organisms through handling. For this process to be successful it is necessary, of course, that the seals be absolutely water-tight, as the bottles are submerged in water, and, during cooling, a defective cap might allow infection by polluted cooling water. The disadvantage of this process is in the increased cost of pasteurization, caused by the cost of the seal caps. It is claimed, however, that the saving in milk losses by pasteurization in bottles makes up

for the added expense of caps. It is now possible to pasteurize milk in this manner without using water-tight caps. This is accomplished by the aid of devices which fit over the tops and necks of the bottles, thereby protecting the ordinary paper caps from the water which is sprayed on the bottles for the purpose of heating or cooling. This method of protecting the tops permits the use of the ordinary caps and removes the possible danger of polluted water infecting the milk.

Another method of pasteurization, or, rather, a modification of the present holder process, is that of bottling hot pasteurized milk. Work on this process was begun in 1911, and the process was first suggested by the author (4) in 1912; further work on this subject may be found in an article published in 1914 (5). The process consists in pasteurizing milk by the holder method at 145° F. for 30 minutes, then bottling, while hot, in hot, steamed bottles. The bottles are steamed for two minutes immediately before filling. After filling with hot milk and capping with ordinary caps the bottles may be cooled at once by any of the systems in which the caps are protected and the bottles sprayed with water, or the forced cold-air circulation may be used.

The use of forced-air circulation for cooling milk is entirely new, and while only suggested in the paper describing the process of bottling hot pasteurized milk, recent experiments with it for cooling indicate that it is practicable. We have obtained bacteriological results which show that this process is always as good as, and often superior to, the process of pasteurization in bottles. The results of these experiments are being prepared for publication. While working on this process of bottling milk hot it was found that a similar process was patented several years ago. It was described by De Schweinitz (6), and recently two other patents on the process have appeared.

ADVANTAGES OF LOW-TEMPERATURE PASTEURIZATION.

In general the trend of pasteurization is toward the holder process, and with this tendency the use of lower temperatures is becoming more common. As a general rule, when the holder process is used milk is heated to 145° F. for 20 or 30 minutes and to at least 160° F. for 1 minute when the flash process is used. From bacteriological, chemical, and economical standpoints it is highly desirable that milk be pasteurized at low temperatures.

From a bacteriological standpoint, pasteurization at 145° F. for 30 minutes gives assurance, so far as we know, of a complete destruction of disease-producing bacteria, and at the same time leaves in the pasteurized milk the maximum percentage of the bacteria that cause milk to sour (lactic-acid bacteria) and only a small percentage of

those that cause it to rot (peptonizers). When higher temperatures are used, while the total number of all kinds of bacteria is reduced, the percentage of lactic-acid bacteria becomes less and less and the peptonizing group increases until at 180° F., or above, when the lactic-acid bacteria are practically destroyed and the most of the bacteria left belong to the peptonizing group. The heat-resistant lactic-acid bacteria which survive pasteurization at 145° F. for 30 minutes play an important rôle in the souring of commercially pasteurized milk.

From a chemical standpoint the advantage of low temperatures is in the fact that milk pasteurized at 145° F. for 30 minutes does not undergo any appreciable change which should affect its nutritive value or digestibility. According to Rupp (7) the soluble phosphates of lime and magnesia do not become insoluble, and the albumin does not coagulate. At 150° F. about 5 per cent of the albumin is rendered insoluble, and the amount increases with higher temperatures to 160° F., when about 30 per cent of the albumin is coagulated. The heating period in Rupp's experiments was 30 minutes.

From an economic standpoint the advantage of pasteurization at low temperatures is in the saving in the cost of heating and cooling the milk. Bowen (8) has shown that the flash process of pasteurization requires approximately 17 per cent more heat than the holder process. There is, of course, a correspondingly wider range through which the milk must be cooled, which also adds to the cost of pasteurizing. This is owing to the fact that in the holder process milk may be heated to 145° F. and held for 30 minutes, while to obtain the same bacteriological efficiency with the flash process, with one-minute heating, the milk would have to be heated to 165° F.

TEMPERATURES AND METHODS MOST SUITABLE FOR PASTEURIZATION.

In view of the advantages of low-temperature pasteurization, it is advisable to pasteurize milk at 145° F. for 30 minutes. It has been found that heating at 140° F. for that length of time will destroy pathogenic bacteria, but in practice it is advisable to use a temperature several degrees above the limit of safety. During extensive studies of the effect of different temperatures it has been shown that an increase of 5 degrees above 140° F. produces a great increase in the destruction of bacteria in milk.

The holder process, as previously described, is entirely satisfactory when properly used. Considerable attention is necessary, however, to see that the milk is not contaminated during cooling and capping.

Pasteurization in bottles eliminates the danger of reinfection, provided no water is introduced into the bottles during cooling.

From a sanitary standpoint this process is very satisfactory. In the past, on account of the difficulty of treating large quantities of milk, pasteurization in bottles has not been used to any great extent in large plants.

The bottling of hot pasteurized milk in steamed bottles is a process which eliminates the danger of reinfection and can easily be adapted to the treatment of milk in large quantities.

Any one of these methods of pasteurization is satisfactory, provided a temperature of 145° F. is maintained for 30 minutes and reinfection is prevented during subsequent handling of the milk.

SUPERVISION OF THE PROCESS OF PASTEURIZATION.

As is the case with almost every known process which permits of variation by the operators, the process of pasteurization is frequently performed improperly. This is attributable sometimes to lack of care on the part of the operators, but probably more often to lack of proper knowledge of the functions of the process. Pasteurization calls for supervision by competent inspectors to remedy such conditions, and supervision is provided for in only a few of the larger cities. In these cities the process must be performed by machines approved by the boards of health, and at such temperatures and for such periods of holding as are required.

In some cities pasteurized milk must be marked "Pasteurized," and in some cases the temperature must be stated, together with the date of pasteurization.

In most of our cities there is a great lack of proper control over the process of pasteurization, and a standard method of pasteurization and definite procedure for proper supervision of the process is greatly needed.

The process of pasteurization is by no means "foolproof." It demands a knowledge on the part of the operator of the action of the process and its objects. Not all operators have such knowledge. Records obtained in 1912 from 231 milk plants showed that 99 per cent of those which used the holder process pasteurized at the proper temperature. Among those which used the flash process only 57 per cent employed temperatures high enough to give satisfactory results, while in the other 43 per cent the temperatures were too low to be effective in the destruction of pathogenic bacteria. At the present time this condition is much improved.

Anyone who has had the opportunity to examine the numerous plants where pasteurization is practiced has undoubtedly found cases in which as many bacteria were introduced in cooling and bottling as were destroyed by the heating process. It is in such cases that the operator's ignorance of the fundamental principles of the process is

most strikingly shown. One false step, such as running pasteurized milk through a piece of dirty cheesecloth before it enters the bottle filler, may undo all the previous work. Pasteurization is an added expense, and merely as a matter of business, it is hard to believe that after the process is properly performed anyone would willfully allow the results to be spoiled by a single operation, no matter whether the object of the process is to produce a sanitary milk or merely to preserve it. The failure of a few plants to pasteurize properly is no reason for condemning the process. In such cases a little education will often produce marked improvement and enable the milk dealer to meet city regulations.

The control of the process of pasteurization should be based only on accurate scientific data. In the past it has often been the practice to expect a bacterial reduction of 99 per cent during pasteurization. While it is an easy matter to destroy 99 per cent of the bacteria when the raw milk contains large numbers, it is often impossible, on account of heat-resistant bacteria which are not necessarily spore formers, to destroy 99 per cent when the milk contains about 100,000 bacteria per cubic centimeter. In a large number of experiments in which milk was pasteurized under exact laboratory conditions, where no reinfection was possible, in one sample only 17 per cent of the bacteria were destroyed. Often 99 per cent of the bacteria may be destroyed, and yet the milk may still contain hundreds of thousands, while in other cases in which it contains only tens of thousands, the per cent of reduction may have been only from 80 to 90. The efficiency of the process can not be based on the per cent of bacteria destroyed.

In the control of pasteurization it is essential that the proper temperature be used and that the process be so performed that no reinfection takes place. This can be accomplished best by direct supervision of milk plants by trained men who have authority to carry on such supervision, and by bacteriological control of the process.

HANDLING PASTEURIZED MILK.

The pasteurization of milk destroys about 99 per cent of the bacteria; consequently the milk is not sterile. On account of this fact pasteurized milk is still a perishable product, and must be handled with the same care as raw milk. This is a point for both the consumer and the milkman to remember.

Milk after pasteurization should be cooled to about 40° F. and kept at that temperature until delivery. During warm weather it should be iced on the delivery wagons. From a sanitary standpoint all milk, whether raw or pasteurized, should be delivered as soon as possible, in order that the consumer may get it in the best condition.

In the best pasteurized milk, when held at about 40° F., there is only a slight bacterial increase during the first 24 hours. In many cases the pasteurization and delivery may be so arranged that the consumer gets the milk before much, if any, change has taken place in the bacterial content. The tops of the bottles should have overlapping caps to protect them from dust, dirt, or other contamination, and the cap should be marked "Pasteurized" and show the date and the temperature at which the milk was treated. For the benefit of the consumer this information should be printed on the cap, as it is only right for him to know whether he is using raw or pasteurized milk, and if pasteurized, the temperature may be of importance to him. Some people object to pasteurized milk, especially for infant feeding, while others desire it. It has been the experience of numerous milk dealers that the labeling of their product has greatly increased their trade.

COST OF PASTEURIZING MILK.

The cost of pasteurizing milk is a matter of considerable importance. It has been found by Bowen (*loc. cit.*) that the average cost of pasteurizing 1 gallon of milk is a little more than three-tenths of a cent (\$.00313). He obtained this information from a series of tests in five establishments which were considered to represent the average city milk plant. The pasteurizing equipment in each consisted of a heater, a holding tank, a regenerator, and a cooler. The cost of the operation was based on the pasteurizing cycle, starting with the initial temperature of the raw milk and raising it to the pasteurizing temperature, then cooling to the initial temperature of the raw milk. He based the costs on daily interest at 6 per cent per annum on capital invested in pasteurizing equipment, and depreciation and repairs per day at 25 per cent per annum, interest per day at 6 per cent per annum on capital invested in mechanical equipment for pasteurizing, and depreciation and repairs per day at 10 per cent per annum. Other costs figured were labor, coal at \$4 a ton, cooling water at 50 cents a thousand cubic feet, and refrigeration at \$1 a ton.

BACTERIA WHICH SURVIVE PASTEURIZATION.

Earlier in this paper it is stated that about 99 per cent of the bacteria in milk are destroyed by pasteurization; consequently about 1 per cent of the bacteria remain alive in the milk, and that just what kinds are left depends entirely on the temperature to which the milk is heated. From studies of the bacteria which survive pasteurization (9) it is possible to show graphically the hypothetical relations of the bacterial groups in raw milk and in milk pasteurized by the holder process at various temperatures under laboratory conditions.

The bacterial flora of the various kinds of milk is represented in figure 1 by columns of equal length divided into sections, which, in a general way, show the relative proportion of the bacterial groups.

From the figure it may be seen that raw milk contains four principal groups of bacteria—the acid, inert, alkali, and peptonizing

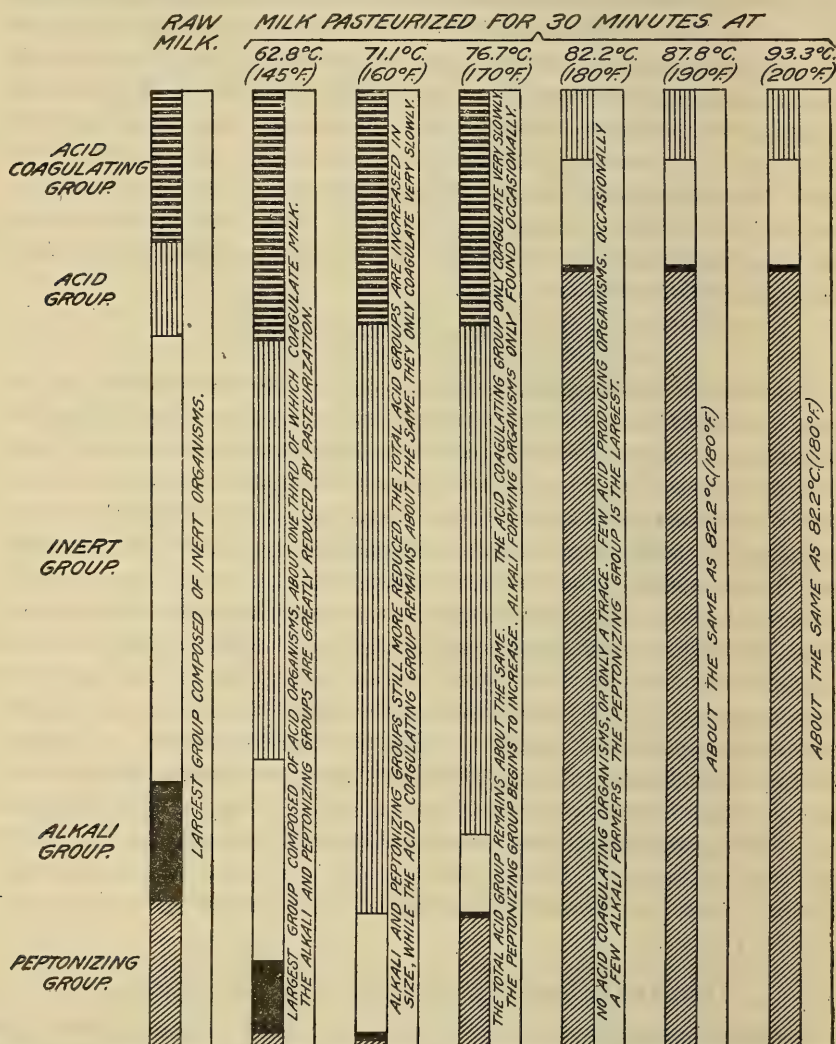


FIG. 1.—The hypothetical relation of the bacterial group to raw and pasteurized milk.

groups. The acid group is divided again into two, the acid-coagulating, which coagulates milk within 14 days, and the acid group, which merely produces acid and does not coagulate it in less time than that. In raw milk the inert group is the largest.

In milk pasteurized at 145° F. the great increase in the proportion of the acid-coagulating and acid groups is plainly shown. The per cent of the alkali and peptonizing groups is reduced. At 160° F. the total-acid group is still the largest, but the acid-coagulating group is made up of bacteria which coagulate very slowly. At this temperature the alkali group is greatly reduced, and the peptonizing reduced to the minimum. At 170° F. the total-acid group remains about the same, but the organisms produce acid and coagulate the milk very slowly. The alkali group is practically destroyed, although occasionally a sample may show a fairly high per cent. The most important change is in the peptonizing group. At this temperature the ratio of this group to the total number of bacteria begins to increase. The increase when milk is pasteurized at 180° F. is even more striking. At this temperature more than 75 per cent of the bacteria which survive are peptonizers. No organisms of the acid-coagulating group are found, and only a small per cent of the acid group. Occasionally a few of the alkali group may be found. At 190° F. and 200° F. the bacterial groups which survive are about the same in their relative sizes as at 180° F.

It is very evident that when the bacterial flora of pasteurized milk is under discussion the temperature of the process is of fundamental importance. From figure 1 the bacterial groups left in milk pasteurized at different temperatures may be seen at a glance. It must be remembered, however, that the relations of the bacterial groups represent only average conditions and that the bacterial flora of every sample of milk must not be expected to conform exactly to these averages. Variations in methods and conditions in the production of milk may considerably influence the bacterial group relations of an individual sample.

The results in figure 1 may perhaps be better explained in popular terms. When milk is pasteurized at 145° F. for 30 minutes, the most of the bacteria (lactic-acid bacteria) left alive in it are of the kind which causes it to sour, and there are present only a few bacteria (peptonizing) which cause it to rot. As the milk stands, the acid formers grow and cause the milk to sour instead of rot. When milk is pasteurized at 180° F. for 30 minutes, however, the bacteria (lactic-acid) which cause the souring of milk are practically all destroyed, and those which are alive (peptonizing) continue to grow and cause the milk to rot.

Since the general groups of bacteria which survive pasteurization have been discussed, let us now consider a more specific group. It has been the custom of some authorities to consider the presence of streptococci in pasteurized milk an indication of an ineffective process. In a recent study (10) of the subject, however, it was

found that certain strains of streptococci are able to survive pasteurizing temperatures.

The thermal death points of 139 cultures of streptococci isolated from cow feces, from the udder and mouth, and from milk and cream, showed a wide variation when the milk was heated for 30 minutes under conditions similar to pasteurization. At 140° F., the lowest pasteurizing temperature, 89 cultures, or 64.03 per cent, survived; at 145° F., the usual temperature for pasteurizing, 46, or 33.07 per cent, survived; and at 160° F., 2.58 per cent survived; all these were destroyed at 165° F. The streptococci from the udder were, on the whole, less resistant, and those from milk and cream more resistant to heat than those from the mouth and feces of the cow.

Two classes of streptococci seem to survive pasteurization: (1) Streptococci which have a low majority thermal death point: (the temperature at which a majority of the bacteria are killed), but among which a few cells are able to survive the pasteurizing temperature. This ability of a few bacteria may be owing to certain resistant characteristics peculiar to them or may be caused by some protective influence in the milk. (2) Streptococci which have a high majority thermal death point, and which, when such is the case, survive because this point is above the temperature of pasteurization. This ability to resist destruction by heating is a permanent characteristic of certain strains of streptococci.

It is evident that certain varieties of streptococci are able to survive pasteurization, while others are probably always destroyed. Numerous investigators have studied the thermal death point of streptococci isolated from patients having septic sore throat and have found that the organism was destroyed by pasteurization at 145° for 20 minutes. These results, together with the protection which proper pasteurization seems to afford against epidemics of that disease caused by milk supplies, indicate that the varieties of streptococci associated with or responsible for the disease are among the varieties which have a low thermal death point.

In a similar study (11) of the ability of colon bacilli to survive pasteurization it was found that certain strains could survive pasteurization at 145° F. for 30 minutes. On examining 174 cultures of colon bacilli it was found that at 140° F., the lowest pasteurizing temperature, 95 cultures survived; at 145° F., the usual temperature for pasteurization, 12 survived. In each case the heating period was 30 minutes. Considerable variation was observed in the thermal death point of the colon bacilli which survived at 145° F. When the cultures which withstood the first heating were again heated it was found that many did not survive, and in each subsequent heating different results were obtained. Colon bacilli have a low majority

thermal death point and, on account of the survival of a few cells, survive the pasteurizing process.

The colon test as an index of the efficiency of the process of pasteurization is complicated by the ability of certain strains to survive a temperature of 145° F. for 30 minutes and to develop rapidly when the pasteurized milk is held under certain temperature conditions which might be met during storage and delivery. Consequently the presence of a few colon bacilli in pasteurized milk under ordinary market conditions does not necessarily indicate that the milk was not properly heated. The presence of a large number of colon bacilli immediately after the heating process may, however, indicate improper treatment of the milk.

If milk is pasteurized at a temperature of 150° F. or above for 30 minutes, it is not to be expected that any colon bacilli will survive; consequently under such conditions the colon test for the effectiveness of pasteurization may be of value. It must be remembered, however, that a study of more cultures may reveal strains of colon bacilli that are able to survive this or even a higher temperature.

MODERN THEORIES OF PASTEURIZATION.

Pasteurization at present is looked upon with favor by medical men, sanitarians, dairymen, and consumers, but the art has not been developed without opposition, and even now its value is not universally accepted. Most of the objections to pasteurized milk have been based on theory or on experiments in which the milk was pasteurized at high temperatures and in view of our modern theories are of no great importance.

One of the greatest objections to pasteurized milk has been that the heating destroyed the lactic-acid bacteria and that putrefactive organisms were left, which, when relieved from the restraining action of the acid-forming bacteria, would develop, forming toxins and putrefactive products (12). It was believed that the milk, because it was not sour, would be consumed in that condition. This objection was based on experiments in which milk was heated to temperatures near the boiling point and can not be applied to milk pasteurized at low temperatures. From the results of seven years' work in the Dairy Division on commercial pasteurized milk it has been found that such milk sours, as raw milk does, but that the souring is delayed. Pasteurization for 30 minutes at temperatures of about 145° F., as is generally practiced in this country, does not destroy all the lactic-acid organisms, and those which survive play an important rôle in the souring of commercially pasteurized milk.

Another objection to pasteurized milk has been that bacteria grow faster in it than in raw milk. In spite of several experiments which

seem to prove this point, it has never been thoroughly established. It has been found that the rate of bacterial increase is approximately the same when the comparison is made between raw milk and pasteurized milk having about the same bacterial content.

It is often stated that pasteurization, even if it does destroy bacteria, does not destroy poisonous products of their growth. This can hardly be considered a real objection, for if they are present in raw milk they must be consumed with it, and if pasteurization does not destroy them the pasteurized milk would be no worse than the raw milk.

The question as to whether pasteurization destroys beneficial enzymes is still an open one. In the light of our present knowledge of the enzymes in milk and the part they play in the digestive process it is quite impossible to settle the question of their importance. It is evident, however, that the low temperatures now in use in pasteurization have little effect on the commonly recognized enzymes.

The opponents of pasteurization have raised an objection on the ground of its direct influence on the milk producer. It has been asserted that pasteurization would cause lax methods of production on the farm, for the reason that farmers would know that the milk was to be pasteurized and, therefore, they could be careless in its production. There seems to be some basis for this objection, but in any city where there is any inspection of the raw-milk supply the same inspection can and should be continued even though the milk is to be pasteurized.

From a chemical standpoint serious objections have been raised against pasteurized milk, because the heating produces changes which render the milk less digestible, particularly in the case of infants. As has already been stated, however, Rupp has found that milk pasteurized at 145° F. for 30 minutes does not undergo any appreciable chemical change. He found that soluble phosphates do not become insoluble, that the albumin does not coagulate, and that when higher temperatures are used chemical changes do occur. He also developed the fact that 5 per cent of the albumin is rendered insoluble in milk heated for 30 minutes at 150° F., while at 160° F. 30.78 per cent of the albumin is coagulated. It is evident that the use of low temperatures for pasteurization overcomes any objections which may be raised on the ground of chemical changes.

Further evidences that low-temperature pasteurization does not injure the digestibility and nutritive value of the milk is shown by the results of feeding experiments on babies. According to Weld (13) a number of babies that were fed raw milk and pasteurized milk showed only a slight difference in the average net daily gain in weight during the feeding period. The slight difference was in favor of pasteurized milk.

High-temperature pasteurization of earlier days must not be confused with low-temperature pasteurization of the present day. Many of the objections which have been raised to pasteurization have been founded on the observation of milk heated to high temperatures. Unfortunately, not until recently has the use of low temperatures entirely changed our views in regard to the value of pasteurization. The fallacy of the objections to pasteurization has been shown, however, through scientific research in the past few years, and as a result the value of the process has been firmly established.

THE NECESSITY FOR PASTEURIZATION.

Although pasteurization is being more extensively practiced in most cities, particularly the larger ones, there are health departments in some of the smaller cities which are strongly opposed to the process; there are also many people who object to it. The problem of pasteurization is not based simply on the question of which is preferable, raw or pasteurized milk, but rather upon the most economical and practical way of producing a safe milk supply. In small cities where money enough is available to pay for inspection, and where the milk supply is drawn from farms within a short distance of the city, it may be feasible, without pasteurization, to bring the supply to a point of reasonable safety. To produce, however, the same degree of safety in the supply of a large city by inspection would involve a tremendous expense.

Let us consider for a moment the supply of New York City, which in 1912 amounted to about 2,500,000 quarts daily. This milk came from 44,000 farms in six States, and was the product of about 350,000 cows. Some of it had to be transported 400 miles or even more. It was estimated that 127,000 people were engaged daily in handling the milk supply of that city. It is hardly necessary to discuss the magnitude of a system of inspection suitable to guarantee a safe milk supply of this size.

There is, of course, in the large cities a small quantity of high-grade raw milk, but it is produced under special conditions and sells at a higher price than regular milk. The cost of such milk makes it prohibitive for use in poor families. The means of creating a safe milk supply for general consumption, especially for large cities, is, then, in inspection, developed to the highest practical degree, followed by proper pasteurization.

It seems probable that within the next few years a large proportion of the milk supply in American cities will be pasteurized. This condition will come first in the larger cities, where the safeguarding of the milk supply is a more difficult problem. For economic reasons, and in recognition of the process as a means of eliminating

certain risks which can not be completely eliminated in any other way, the pasteurization of milk is certain to be the general practice in this country.

The greatest feature of the process of pasteurization, properly performed, is that while no valid objections can be raised against the process, it causes an additional degree of safety in milk produced and handled even under the most effective system of inspection.

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BULLETIN No. 343

Contribution from the Forest Service
HENRY S. GRAVES, Forester



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PROFESSIONAL PAPER

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GROUND-WOOD PULP.

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OBJECT OF THE BULLETIN.

This bulletin presents the results of tests on (a) the grinding of steamed or cooked spruce for mechanical pulp and (b) the results of tests on a number of American woods to determine their suitability as substitutes for spruce in the manufacture of ground-wood pulp.¹ If the price of news-print paper is to be kept at a reasonable figure, more efficient methods of converting spruce into pulp must be developed or else a cheaper wood substituted for the former. The results of experiments meant to develop greater efficiency in the grinding of uncooked spruce have already been presented in Forest Service Bulletin 127, "The Grinding of Spruce for Mechanical Pulp." That bulletin also discusses the influence of the many

¹ Acknowledgment is made to Mr. C. P. Winslow, Mr. Henry E. Surface, and Mr. S. D. Wells, engineers in forest products, and to Mr. S. E. Lunak, assistant chemist in forest products, Forest Service, for aid in the preparation of this report. Acknowledgment is also due Messrs. G. F. Steele, W. G. McNaughton, and L. M. Alexander, of the Nekoosa-Edwards Paper Co., and Mr. D. C. Everest, of the Marathon Paper Mills Co., for assistance rendered during the tests; also to Mr. C. W. Knapp, of the St. Louis Republic, and to Messrs. P. W. Schaeffer and E. D. De Witt, of the New York Herald, for providing the presses upon which the experimental papers were tried out. The maps in this bulletin showing the range of the various tree species were prepared in the Forest Service by Mr. William H. Lamb, assisted by Miss Georgia Wharton.

NOTE.—This bulletin contains valuable information as to the use of various species of wood in the manufacture of paper and is of interest to manufacturers and users of paper.

variable conditions in the manufacture of mechanical pulp, such as surface of stone, pressure with which the wood is forced upon it, peripheral speed, temperature of grinding, etc. Since the conclusions reached in regard to these are applicable to the production of pulp from coniferous woods in general, it is advisable to have a copy of Bulletin 127 at hand when reading the present one.¹

All the tests described in this bulletin were carried on at the Forest Service ground-wood laboratory at Wausau, Wis., a branch of the Forest Products Laboratory, Madison, Wis., in cooperation with the American Paper and Pulp Association, which furnished all the pulp-making equipment for the laboratory, and with an advisory committee consisting of Messrs. G. F. Steele, chairman, and W. G. McNaughton, secretary, Nekoosa-Edwards Paper Co.; D. C. Everest, Marathon Paper Mills Co.; W. L. Edmonds, Wausau Paper Mills Co.; A. M. Pride, Tomahawk Paper Co.; and William Eibel, Rhineland Paper Co.

PRESENT STATUS OF THE GROUND-WOOD INDUSTRY.

Thirty-five to forty-five years ago news paper was made almost entirely of rags. Upon the introduction of the sulphite process of wood-pulp manufacture varying amounts of that product were added to the rag pulp, and later ground wood was made a part of the mixture, but only in small quantities. Ground wood was for many years nothing more nor less than a filler and not expected to add any strength to the sheet produced. There is shown in figure 1 the average contract price (f. o. b. mill) of news-print paper from 1874 to 1912. The effect of the introduction of the cheaper processes is evident.

In 1870 there were only 8 establishments reported which made ground wood, and the product manufactured during that year was valued at \$172,000. Ten years later, in 1880, 50 establishments produced \$2,257,000 worth of ground wood. In 1890, 82 establishments reported products valued at \$4,628,000. In 1900 there were 91 plants reported, which produced 280,520 tons of ground wood for sale, and 77 mills which produced 306,520 tons of pulp for their own use, a total of 168 mills, producing 586,000 tons, valued at approximately \$9,300,000. In 1909 there were produced a total of 1,179,266 tons of mechanical pulp. Of this amount 310,747 tons were manufactured for sale or consumption in mills other than where produced, the value being \$5,649,466. The remainder, 868,519 tons, assumed to have the same value of that made for sale, was worth approximately \$15,780,000, or a total value of product of \$21,430,000.

¹ Copies of Forest Service Bulletin 127 may be procured from the Superintendent of Documents, Washington, D. C., for 15 cents each.

In 1911, 1,229,719 tons of mechanical pulp were produced, an increase of approximately 50,000 tons.

While the industry has developed very rapidly in the United States, the rate of development has not kept pace with the rate of consumption of the product. This is evident from a consideration of the imports and exports of both mechanical and chemical pulp over a period of years, as shown in figures 2 and 3. Figure 2 shows the imports of mechanical pulp, both free and dutiable, by months for a period of years, while figure 3 (curve *B*) shows the imports of mechanical pulp by years. The first of these curves is particularly

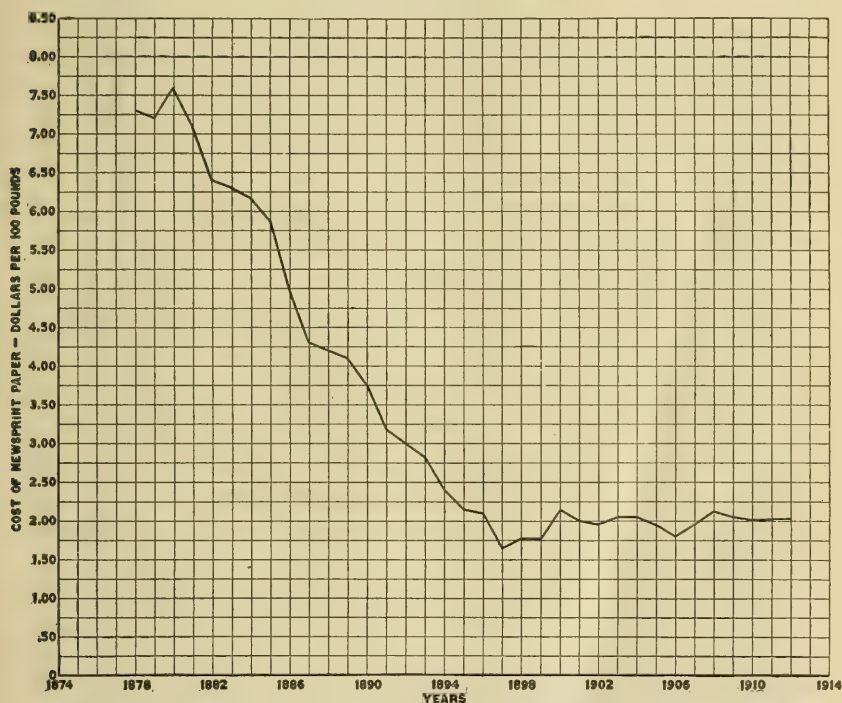


FIG. 1.—Average contract prices for news-print paper 1878-1912.

interesting, because it shows the seasonal fluctuation of imports. Figure 3 (curve *A*) shows the imports and exports of wood pulp, both mechanical and chemical. The increase in the amount of pulp imported is very marked, while the exports are comparatively small. It is evident from these curves that considerably more pulp will have to be manufactured at home before there can be any material expansion into the export trade.

Spruce furnishes by far the greater part of the wood at present used for mechanical pulp. Of the 1,314,141 cords consumed in the United States by the mechanical process in 1911, spruce supplied 1,121,703 cords, or 85 per cent, 822,743 cords of which were native

wood and 298,743 imported. Of the 4,328,052 cords of wood used in the United States in 1911 for pulp of all kinds, spruce furnished 2,505,730 cords, or 57 per cent.

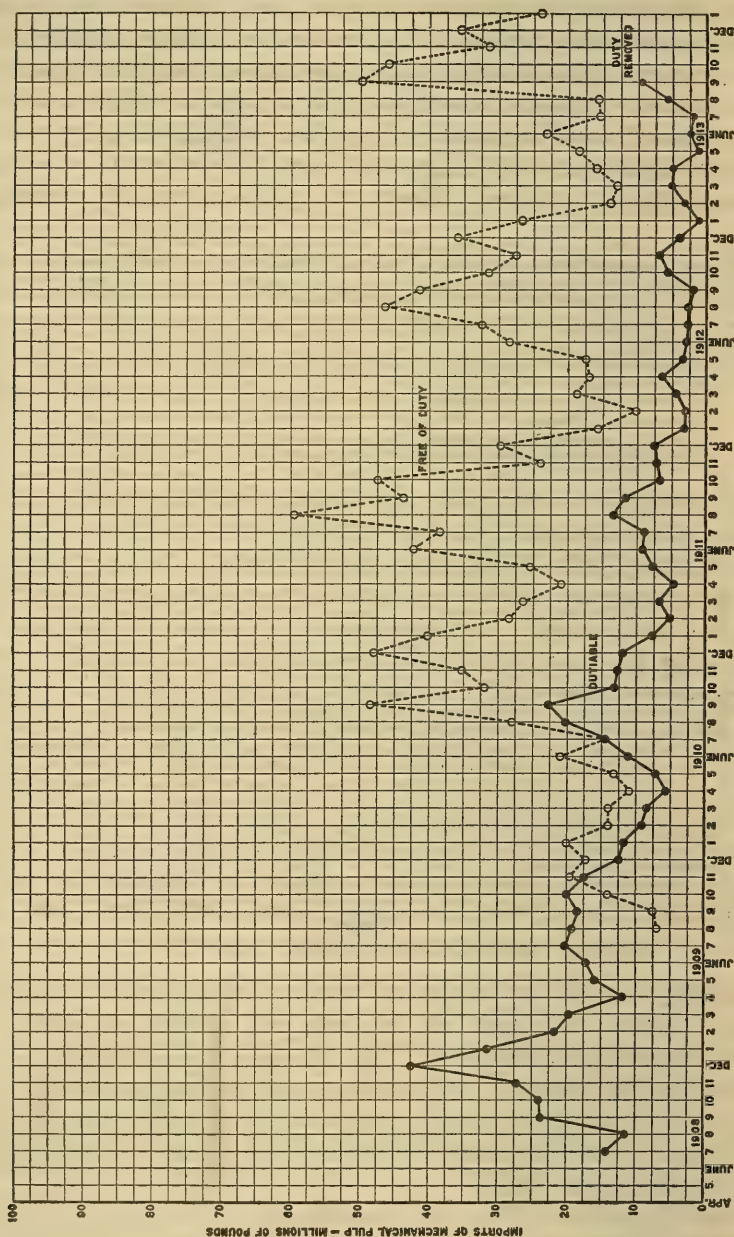


FIG. 2.—Imports of mechanical pulp, July, 1908, to January, 1914, inclusive.

The annual consumption of spruce in this country for all purposes is something like 2,575,000,000 board feet. The available stand east of the Rocky Mountains was estimated in 1907 to be 35,000,000,000

feet, with an annual increment due to growth of 770,000,000 feet. While it is probable that the maximum annual consumption of spruce for lumber has been reached, and that that for pulp wood will scarcely go much higher, it is nevertheless clear that with the maintenance of anything like the present annual consumption the spruce forests of this country are threatened with exhaustion. Nor is it likely that the American consumer of spruce wood will be able to draw to whatever extent he wishes upon the Canadian supply. In 1900 the Province of Ontario prohibited the exportation of unmanufactured wood cut on Crown lands within the Province, and later the Provinces



FIG. 3.—Imports and exports of wood pulp, 1901–1913, inclusive.

of Quebec (1909) and New Brunswick (1911) passed similar legislation. Further restrictive measures regarding the exportation of unmanufactured wood will undoubtedly be taken by Canada if the need arises.

The rise in the price of spruce over the 10-year period from 1900 to 1909, inclusive, reflects a steady increase in the consumption of mechanical pulp and a decrease in the available supply of the wood. In 1900 the average cost of spruce used for pulp-making purposes in the United States was \$4.28 per cord for domestic and \$6.50 per cord for imported material. In 1909 the average price for domestic spruce

had risen to \$8.32 per cord, and for imported to \$11.34 per cord. During the same 10-year period the average cost of manufacturing ground-wood pulp increased from \$10.84 per ton to \$16.58, by far the greater part of this increase being due to the greater cost of the wood used. Thus the manufacturer of mechanical pulp is faced with a steady increase in the cost of his raw material, and one which promises to continue if he must rely almost wholly upon a single wood. The great bulk of mechanical pulp produced is used in the manufacture of news-print paper, and the problem which presents itself is whether woods other than spruce can be used for the purpose. It was to answer this question, at least in part, that the experiments described in this bulletin were undertaken.

PRESENT METHODS OF MANUFACTURE.

The present method of manufacturing ground-wood pulp has been in use for a long time. Since 1867, when the mechanical process was first introduced into this country, principles and methods have changed but slightly. The size and capacity of the grinders have been increased and the raw material changed from poplar to spruce, but otherwise the industry is following its first lines. As in any other industry, however, details of manufacture differ in different mills. Of two mills producing news-print paper, for example, one uses 135 horsepower to the grinder, the other 625. One employs a grinder cylinder pressure of 17.5 pounds per square inch; the other, with a cylinder of the same size, a pressure of 72 pounds. One runs at a peripheral speed of 2,660 feet per minute, the other at a speed of 3,540 feet. Such details of operation may differ among mills producing the same kind of paper even more widely than those just cited. Reports of power consumption show a range of from 31 to 135 horsepower per ton in 24 hours. The first value is undoubtedly wrong, since it has been demonstrated experimentally that such a low power consumption is impossible with the present grinding equipment.

Upon its receipt at the mill the wood is either stored for a considerable time in the yard or else is ponded. Before storage the wood is sometimes cut into 2-foot lengths, or in other cases is rossed.

The grinders ordinarily take a pulp-stone approximately 54 inches in diameter by 27 inches face. Some stones recently installed are as large as 60 inches in diameter and 48 inches face. Up to a few years ago natural quarried stones were the only kind used in the grinding process, but many mills are now experimenting with artificial stones. The grinding is usually carried on under conditions of high temperature brought about by admitting only small quantities of water to the pit of the grinder. In the cold-grinding process, which is sometimes used in the United States and very largely adhered to in Europe, an excess of water prevents any heating.

Upon leaving the grinder a large supply of water is added to the pulp, and the mixture is then screened. If it is to be shipped over a long distance, the pulp is run into laps by means either of wet machines or of hydraulic presses. Occasionally the pulp is dried on steam driers and run into rolls. When pulp is used where it is produced, except for the need of storing to provide a supply in times of low water, it is thickened by means of feltless wet machines or deckers and immediately manufactured into paper.

In the last few years a magazine pulp grinder has come into use, equipped with two pockets which are filled automatically from the magazine. The machine, however, has not been operated in this country to an extent which would enable a judgment to be formed regarding its efficiency and economy.

Part I.—THE GRINDING OF COOKED AND UNCOOKED SPRUCE.

EQUIPMENT USED IN THE EXPERIMENTS.¹

APPARATUS FOR COOKING.

Cooking treatments prior to grinding were carried on in a cylindrical closed steamer 3 feet in diameter by 8 feet high, designed for 75 pounds' working pressure. The "steamer" was fitted with steam, water, and vacuum connections and the necessary gauges and thermometers for determinations of pressure and temperature. An open steamer 6 feet wide, 8 feet long, and 3 feet deep was also available for cooking treatment at atmospheric pressure.

ELECTRICAL EQUIPMENT.

In order to satisfactorily vary the conditions of grinding, secure adequate data on power consumption, and maintain the speed constant, it was necessary to install a rather complex system of electrical drive and control for the grinder. The method of speed regulation was known as the Ward Leonard system, and by its means a very flexible arrangement was secured.

The installation consisted of a motor generator set of 460-kilo-volt-amperes full-load capacity and a direct-current, variable-speed motor having a full-load capacity of 500 horsepower at 300 revolutions per minute. With the overload capacity it was possible to secure fully 75 per cent more power than the rating from each of the machines.

Three-phase 60-cycle electric power was applied to the synchronous motor of the motor generator set at 2,300 volts. The generator of the motor generator set was separately excited and by means of a rheostat

¹ A more detailed description of the equipment of the Forest Service laboratory at Wausau, Wis., is given in an unnumbered publication of the Forest Service, "Experiments with Jack Pine and Hemlock for Mechanical Pulp."

in the field circuit direct current could be generated at any desired voltage from 100 to 700 volts. The direct-current motor connected to the grinder was also separately excited and the speed of rotation controlled by regulating the voltage applied to the armature, the voltage control being brought about by variation of the field current of the direct-current generator. The speed of the grinder motor could be varied from 100 revolutions per minute to 300 revolutions per minute, the capacity with overload at the same time varying from approximately 340 horsepower to 750 horsepower.

The efficiency of the direct-current motor could be determined very readily by means of curves showing the stray power and heat losses at different speeds and current loads and knowledge of the power supplied to the motor. The latter data were obtained by means of accurately calibrated indicating and recording electrical instruments.

The various pieces of apparatus used in the manufacture of the pulp were driven by individual direct-connected motors. The apparatus for wood preparation, 40-inch swing saw, and "Green Bay" barker, together with the wet machine vacuum pump, were driven from a single-belted motor. Some of the individual motors were of the variable-speed type, and as a result the pieces of apparatus to which they were connected could be driven at the most effective speeds.

PULP MACHINERY AND AUXILIARY EQUIPMENT.

All of the pieces of machinery installed in the Wausau laboratory were of commercial size and design and were loaned either by manufacturers or others interested in the work being carried on.

The grinder was built by the Friction Pulley and Machine Works. It took a stone 54 inches in diameter by 27-inch face and had three 14-inch cylinders. Each cylinder was provided with a pressure gauge and the water was supplied by two triplex pumps. The pressure at which the water was pumped was regulated by relief valves; pressures as high as 120 pounds per square inch could be obtained.

A recording thermometer gave a record of the temperature in the grinder pit. From the grinder pit the pulp was passed through a mechanically agitated sliver screen, then pumped to a storage tank by means of a 5-inch centrifugal pump, and from there pumped to a centrifugal screen. A variable-speed motor direct connected to the screen made it possible to obtain speeds of rotation from 400 to 600 revolutions per minute. Throughout the tests, however, the speed was maintained at 500 revolutions per minute. The plate in the centrifugal screen was perforated with holes 0.065 inch in diameter.

The tailings from the centrifugal screen were rescreened through a 12-plate Harmon diaphragm screen, the plates used being the Union Screen Plate Co.'s type B, cut with 0.012-inch slots.

The screened pulps from the centrifugal and the flat screen were united and run out on an Improved Paper Machinery Co.'s 3-roll hydraulic wet machine. The white water from the wet machine was pumped back to the sliver screen of the grinder by means of a 4-inch centrifugal pump. White water from the felts was run to the sewer, as was also the white water from the felt suction.

PAPER-MAKING EQUIPMENT.

Portions of the pulps secured from experimental runs were sent to the Forest Products Laboratory at Madison to be run into paper. The apparatus available for the purpose when the earliest tests were made consisted of a pulp shredder, 12-pound Emerson beater, 2-plate flat screen slotted with 0.012-inch slots, and a 12-inch Fourdrinier paper machine. Later a Noble and Wood's jordan engine was added to the equipment. This was used only, however, in the preparation for the paper machine of pulps made from miscellaneous woods. The stock which was run on the machine in carrying on series tests to determine the effect of variable grinding conditions on the strength of pulp was not jordaned.

METHODS EMPLOYED IN EXPERIMENTAL TESTS.

PREPARATION OF WOOD.

All of the wood received at the laboratory was stored on skids in the yard and in most cases allowed to season before being used. It was received in several different forms; some cut from very large trees was split before shipping; some was rossed in the woods; but the greater part was in the form of round rough logs varying from 4 to 14 inches in diameter. The wood for test was sawed as required into 2-foot sections and barked, samples being taken for the determination of moisture and dry weight per cubic foot. The amount desired for the test was weighed and the diameter of each piece was measured. Tests were conducted as soon as possible after the wood was prepared and weighed.

In some cases it was necessary to remove knots before grinding, especially when the knots were likely to cause dirt in the pulp. This procedure was more often required for jack pine and aspen than for other woods.

In case the wood was to be treated it was piled in the steamer after having been carefully weighed. Depending on the conditions of the cook, the pressure was maintained constant at the desired value for different lengths of time. Cooks were made at steam pressures of from 5 to 75 pounds per square inch and for different lengths of time, from 1 to 12 hours. In some cases the wood was steamed and the condensation was drawn off as it formed; in others, the wood was immersed in water and boiled at different steam pressures, the

condensation being blown off as soon as the temperature fell below that corresponding to the steam pressure in use. In some cases, after cooking the required length of time, the charge was allowed to stand until it had absorbed a large amount of water. After unloading, the wood was weighed and then ground as soon as possible. In several instances samples were taken after cooking and the bone-dry weight and the moisture were determined.

GRINDING.

Before starting the test the desired surface was placed on the stone by means of a mechanically controlled burr or bush roll. The stone was then washed until free from loose sand and an impression of the stone was taken by means of carbon and coated paper. (See Forest Service Bulletin 127.) The grinder pockets were filled, the pressure adjusted to the correct value, the recording instruments were placed in operation, and the test was then started.

The speed and pressure were maintained as constant as possible throughout each test. Pocket binding was eliminated by the constant observation of power applied to the grinder, a falling off in power consumption with pressure on indicating binding. When a piston was raised, instead of allowing the speed to increase, it was held constant by regulation of the voltage on the motor armature.

In series tests in which the surface of the stone was not altered, but the speed, pressure, or temperature were, the data secured may be more or less open to criticism, since the surface undoubtedly changed slightly from one test to another. However, this change was very slight.¹ Likewise, in short tests it was impossible to heat up the stone thoroughly and here also a very slight error was introduced.¹

During the tests readings were taken of power, speed, pressure, temperature, and the like, the intervals of reading being 15 minutes in most cases, although 5-minute intervals were sometimes employed.

LOSSES IN CONVERSION.

While it is highly desirable that the losses occurring in the barking of different woods be determined, it was impossible to investigate this point satisfactorily. Only small amounts of wood were used, in some cases not more than 8 cords, and determinations on such small amounts would not yield reliable results.

The amount of wood used during any test and the amount of wet pulp manufactured was accurately determined by weighing. Moisture samples were taken of both the pulp and the screenings and the bone-dry weight of each determined. In some cases the amount of wood fiber in the white water was secured by measuring the amount

¹ This point is discussed in more detail in Forest Service Bulletin 127, "The Grinding of Spruce for Mechanical Pulp."

of white water used and determining the wood fiber in a sample of it. This proved rather unsatisfactory, and was discontinued on account of the difficulty in removing the wood fiber from the white water sample.

The yield of pulp has been calculated to a basis of 100 cubic feet of solid rossed wood, this factor being thought more satisfactory and accurate than a measured cord, and representing approximately the solid content of a piled cord of 2-foot rossed wood containing 128 cubic feet.

TESTS ON THE PAPER.

The sample of pulp to be run into paper was first shredded and the moisture determined. The required amount was then weighed out and mixed and beaten with a weighed amount of bleached spruce slow-cook sulphite. In some runs, particularly those made on some of the pulps made from cooked woods, the sulphite was dispensed with. The mixture, usually 20 per cent sulphite to 80 per cent ground wood, was beaten until the fibers were separated, generally about 1 hour. The stock was then run out on the paper machine and an uncalendered sample was taken for strength and color tests.

No size, color, or loading was added to any of the sheets, the desire being to present the pulps made from different woods and under different conditions in as nearly comparable conditions as possible.

The uncalendered samples of paper were tested for tensile strength, lengthwise and crosswise, by means of a Schopper breaking length tester, and for bursting strength by means of a Mullen tester. The color tests were made with an Ives tintphotometer and measurements were made of the thickness of the sheet and weight per ream.

EFFECT OF PRELIMINARY TREATMENT OF SPRUCE.

Spruce has been used for many years as a raw material for ground-wood pulp, but the effect of the production of pulp from it under varying conditions has never been given very careful study. Depending on the quality of the product desired, different conditions of grinding must be selected, and in some cases the wood must even be given a cooking treatment prior to grinding. In the manufacture of container board, where great strength is desired and the color is of lesser consequence, strength is often increased by the addition of sulphite or sulphate pulp, screenings, or old paper stock. In the manufacture of news print paper, strength is desired too, but not nearly so much strength, the color, yield, and finishing characteristics here being the prime consideration. The work which has been done on spruce has been carried on with the idea of attempting to increase the efficiency of grinding both from the standpoint of reducing the power consumption and increasing the yield from a cord of the raw material in either the cooking or ordinary ground-wood process, and

to ascertain the influence on the quality and quantity of pulp produced by the variation of the grinding variables, such as surface of the stone, pressure on the cylinders, speed, temperature, etc.

The cooking of wood prior to grinding is attended with a number of changes in the physical characteristics of the wood which greatly influence the quality of the pulp manufactured from it. The cooking condition must be chosen according to the use to which the pulp is to be put. For the manufacture of news-print paper from pitchy woods it is essential that the treatment be a very mild one, and that the duration of boiling or steaming and the temperature at which it is carried on be such as to allow of the fiber being as light in color as possible. Either the pressure, or corresponding temperature, must be low and the cook of long duration, or the pressure higher and the

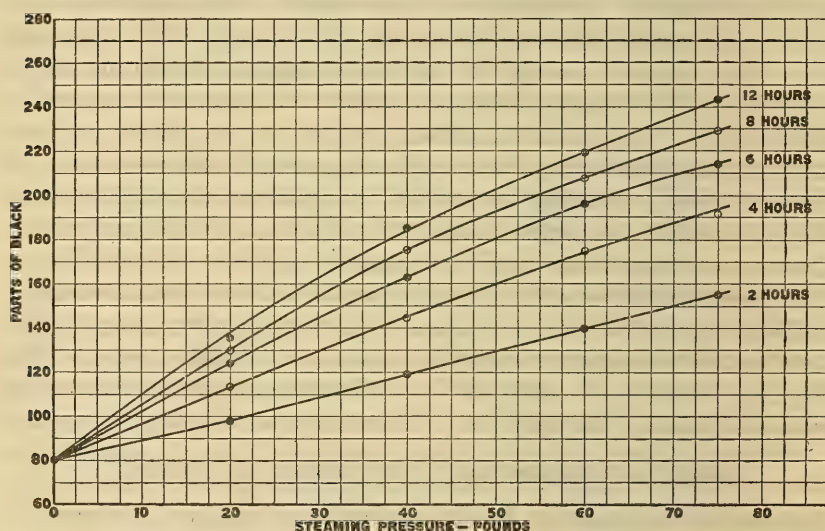


FIG. 4.—Effect of steaming pressure on color of pulp (average values of several runs on spruce).

cook of much shorter duration. It is generally claimed that cooking the wood under pressure while immersed in water will yield a lighter pulp than steaming at the same pressure and for the same length of time, but this result has not been noted.

Boiling wood has certain disadvantages which are not found when the steaming process is used. There is a considerable loss of heat, and it is necessary to draw off condensed liquors to maintain the temperature at any desired value. This makes it necessary to pay greater attention to the process. If the temperature and duration of the cook are the same, the steamed or boiled wood should be practically the same in color and other physical characteristics. One decided advantage of steaming is the possibility of draining off the condensed liquors in a concentrated form. This is of great benefit when by-products are to be recovered.

In all of the experiments conducted in cooking wood prior to grinding, the temperature corresponded to the temperature of boiling at the steam pressure under which the cook was being made. Attempts were made to secure by-products, but the amounts of wood used were so small that this could not be done satisfactorily.

INFLUENCE OF PRESSURE, TEMPERATURE, AND TIME OF COOKING.

When the length of time of the cook is kept constant and the cooking pressure or temperature is varied, it is found that the color of the pulp made darkens greatly when these factors are raised, all other conditions being the same. This is demonstrated by reference to the

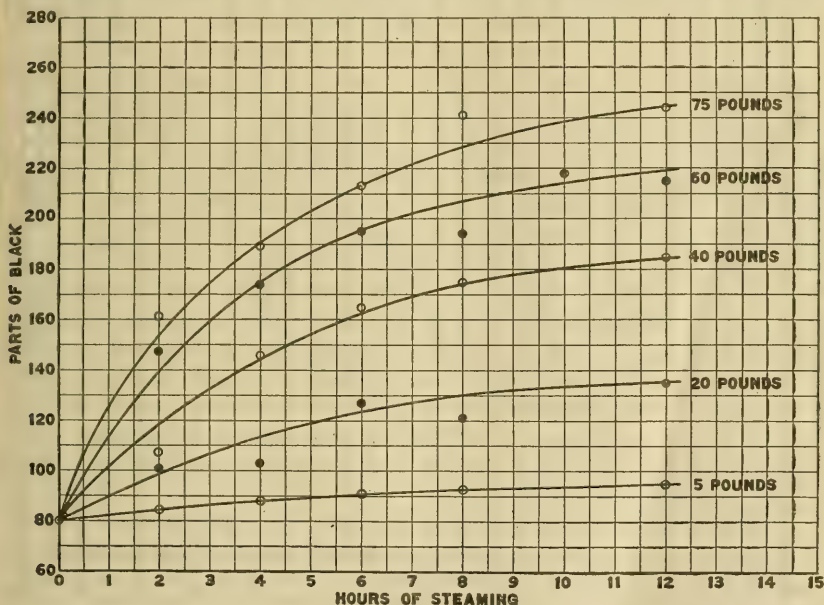


Fig. 5.—Effect of duration of steaming on color of pulp. (Average values of several runs on spruce.)

curves in figures 4 and 5, where the amount of black in the color as determined by a tintphotometer is plotted against the cooking pressure and temperature. At some steam pressure the wood will char and the resultant pulp will be black; under this condition a maximum of 300 parts black would be secured. It is probable that this steam pressure would not be very high, since the values of parts of black increase rapidly after 60 pounds pressure is reached.

The strength of the pulp increases with the length of the steaming period (fig. 6) and seems to reach a maximum in about 8 hours for both pressures. In figure 7 is shown the variation of the yield of pulp per 100 cubic feet of solid rossed wood, with the pressure of steaming and the duration of the cook. The marked effect of the duration of the cook, especially at high pressure, is evident. The yield decreases

rapidly with increased pressure due to the dissolving action of the water and the transformation of portions of the wood into water soluble material which is washed out in the grinding process.

Variation of the period of cook also has a marked influence upon the horsepower consumption per ton of pulp. When wood is ground under the same conditions of grinder pressure, speed, temperature, etc., it is found that after a period of four to six hours of cooking the maximum value of power consumption is obtained. For a greater

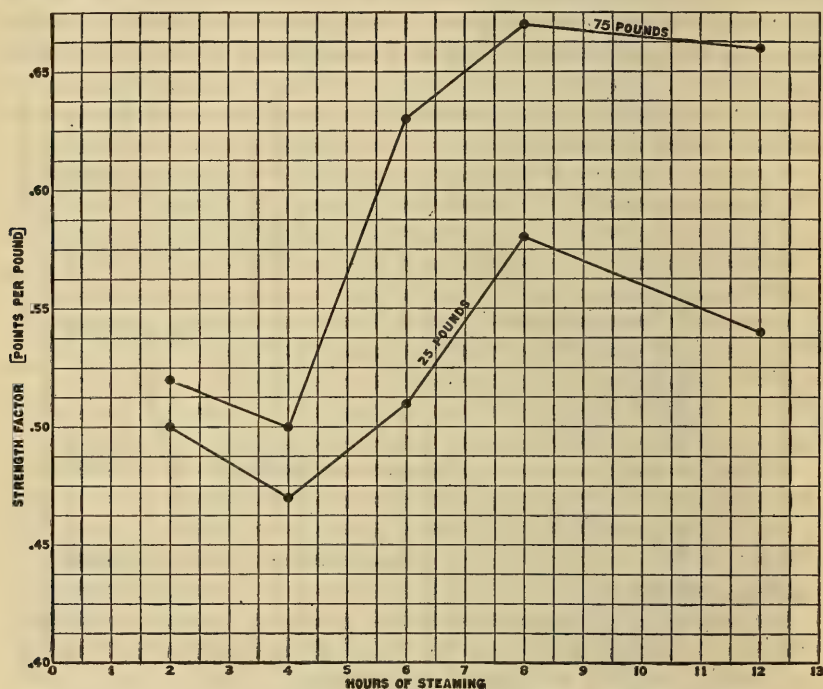


FIG. 6.—Effect of duration of steaming upon the strength of the pulp. (Spruce runs 199-209, inclusive.)

or lesser length of time of cooking the horsepower consumption per ton decreases (fig. 8).

OTHER FACTORS.

The variation of the yield of pulp from 100 cubic feet of solid wood with the duration of cook and temperature of cooking has been pointed out. It would seem that most of the loss would occur in the cooking process itself, but determinations of the amount of bone-dry wood charged to the cooker and the amount of bone-dry material taken from it after steaming shows that the loss in cooking as volatile materials and water-soluble substances which leach out when the wood is in the 2-foot lengths is remarkably low, being from 5 to 8 per cent. It appears that the great loss which takes place in the produc-

tion of steamed wood pulp occurs in the grinding process, either due to the dissolving of material which has been converted to a soluble state or the grinding of the softer portion of the wood—the springwood—to flour and the subsequent loss of it in the white water. There is a characteristic odor of burned sugar during the steaming of wood, and possibly some of the wood fiber is converted into sugar.

The condensed liquor from the steamer has a very corrosive action on the iron and it is possible that in order to satisfactorily protect

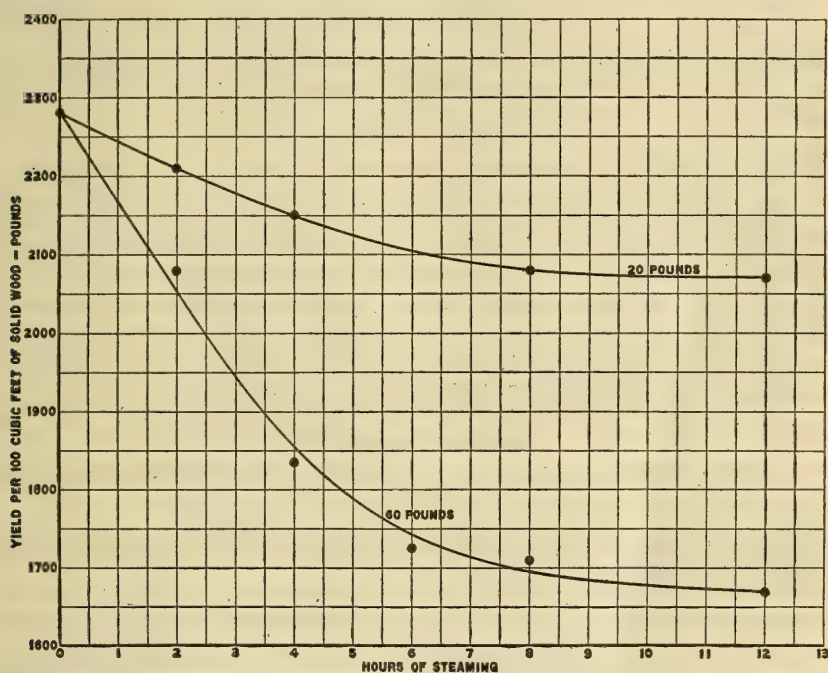


FIG. 7.—Effect of duration and pressure of steaming on the yield of pulp. (Spruce runs 103 to 107 and 114 to 119, inclusive.)

the metal it might be desirable to add small quantities of sodium carbonate to the water when the boiling process is used. This, of course, would not apply when the wood is steamed.

The liquors which condense during the steaming of the woods may have considerable commercial value, particularly when resinous woods are used. The equipment employed in the Wausau laboratory was not of sufficient capacity to make it possible to study this problem carefully, but an indication of the nature of the condensed liquor can be obtained from the following analyses of material secured from a mill steaming wood commercially, in which case approximately 5 cords of wood were used for each charge. Unfortunately no means were available for measuring the total condensed

liquor, and for that reason the amount of the materials can not be expressed in quantity per cord.

It will be noted that two samples were analyzed, one of which was a residue from evaporation of a condensed liquor and the other a sample of the liquor from another cook. The woods steamed were a

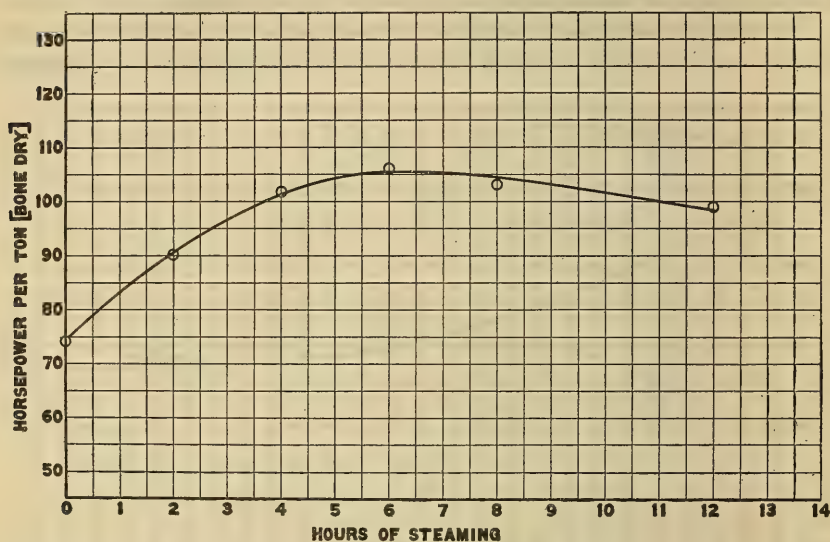


FIG. 8.—Effect of duration of steaming on power consumption per ton of pulp. (Spruce runs 114-119, inclusive.)

mixture of jack pine and tamarack in the ratio of 67 per cent of the former to 33 per cent of the latter.

	Residue from evapo- ration of liquor.	Sample of liquor.		Residue from evapo- ration of liquor.	Sample of liquor.
	<i>Per cent.</i>	<i>Per cent.</i>		<i>Per cent.</i>	<i>Per cent.</i>
Total solids		2.05	Ash	9.85	0.049
Soluble solids.....	70.10	1.95	Acetic acid (total).....	5.71	.162
Reducing sugars.....	15.89	.83	Formic acid (total).....	1.41	.042
Tannins.....	13.60	.092	Moisture.....	4.31	97.95

The total and soluble solids and tannin were determined according to the methods outlined by the American Leather Chemists' Association.

The boiling or steaming of woods results in the formation of a natural size from the wood substance or some of its constituents. This sizing action is particularly noticeable in the production of pulps from the hardwoods—birch and aspen—which are not pitchy. All paper produced from cooked woods, pulped by the mechanical process, show the characteristic water-resistance qualities and hardness of hard sized papers.

Tests on papers made from steamed and unsteamed woods show that the unsteamed pulps do not give as high percentage stretch as the steamed, even though the unsteamed pulps were mixed with 20 per cent of bleached spruce sulphite. Pulps made from cooked woods should be given satisfactory beating treatments to make them usable for different purposes. Like chemical pulp, there is a marked influence on the resultant paper when the pulps are given different beating treatments. The sheets become more brittle after a prolonged beating, but give high strength tests.

THE EFFECT OF GRINDING STEAMED AND UNSTEAMED WOODS UNDER VARIABLE CONDITIONS.

SURFACE OF STONE.

There is shown in figure 9 a series of curves on steamed and unsteamed woods which were conducted on different surfaces of stone. It is evident that the horsepower consumption per ton when steamed wood is used decreases to a minimum value at a grinder pressure of approximately 65 pounds per square inch on a 14-inch cylinder, regardless of the surface which is used. The contrast in the form of the curves for steamed and unsteamed wood is shown in this same figure. Curves 2 and 3 were run under exactly the same conditions, except that in one case steamed wood and in the other unsteamed wood was used as a raw material.

Upon the condition of the surface of the pulp stone depends, to a great extent, the power consumption per ton of pulp made, the rate of production, and the quality of the resultant material. The pulp stone used in the tests was burred in many different ways, and it was generally found that if the grit were brought to the same condition of sharpness, the power consumption, rate of production, and quality of pulp would be practically the same. When the stone is rough but the sand particles are not sharp, a coarser pulp is produced which acts more free on the wire of the paper machine. It was also found that regardless of the degree of sharpness of the stone it was impossible to obtain pulp for news print if the expenditure of power remain 50 horsepower per ton.

Figure 10 shows by curves obtained at different pressures the relation of three different surfaces of stone to the power consumption per ton, power to the grinder, and production in 24 hours. These typical curves show how greatly the above-mentioned factors are influenced by varying the sharpness of the pulp stone.

Plates I and II show the effect of different degrees of sharpness of stone on the quality of pulp produced as represented by the character of fibers. Plate I, figure 1, shows the fiber produced on the sharper medium grit stone with the consumption of a small amount of power,

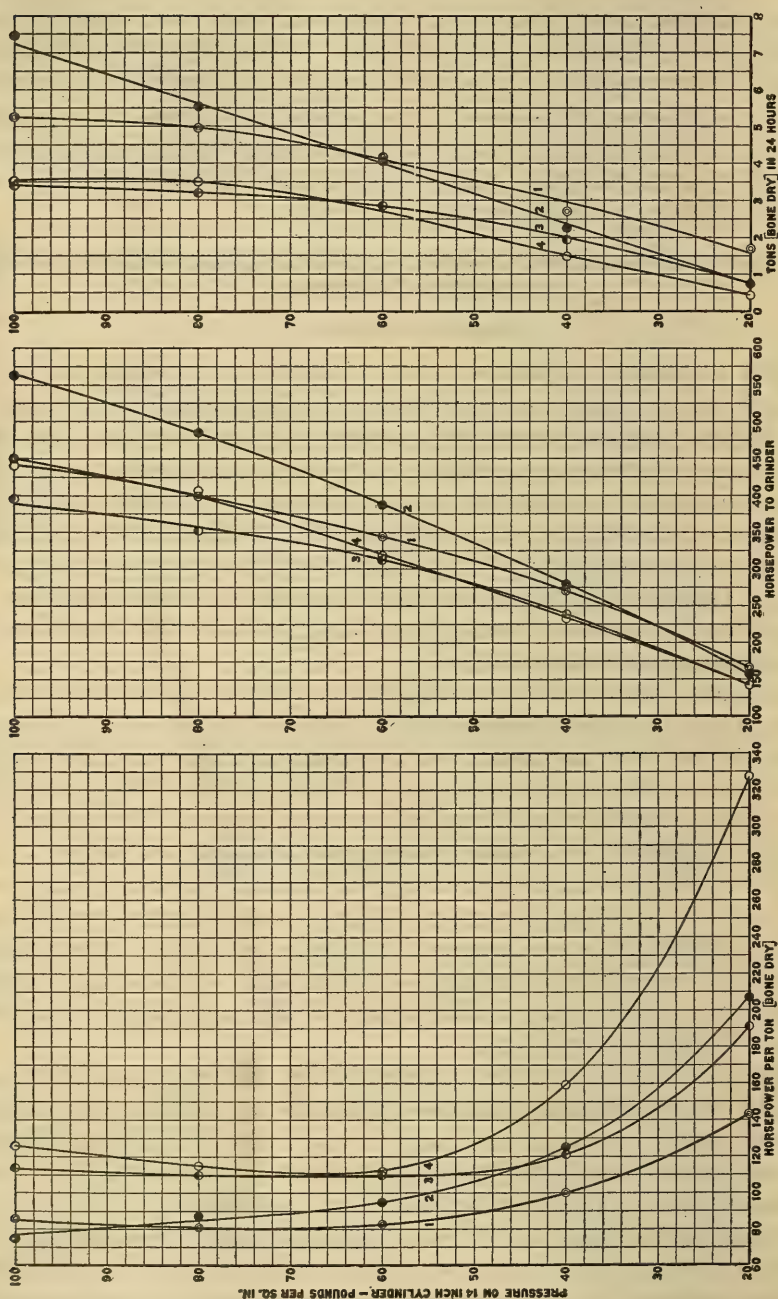


Fig. 9.—Relation of power consumption and rate of production to pressure. 1. Steamed spruce runs 182-187, inclusive. 2. Unsteamed spruce runs 177-181, inclusive. 3. Steamed spruce runs 172-176, inclusive. 4. Steamed spruce runs 167-171, inclusive.

while figure 2 shows that the consumption of a greater amount of power on a duller stone yields a much finer and better fibered pulp.

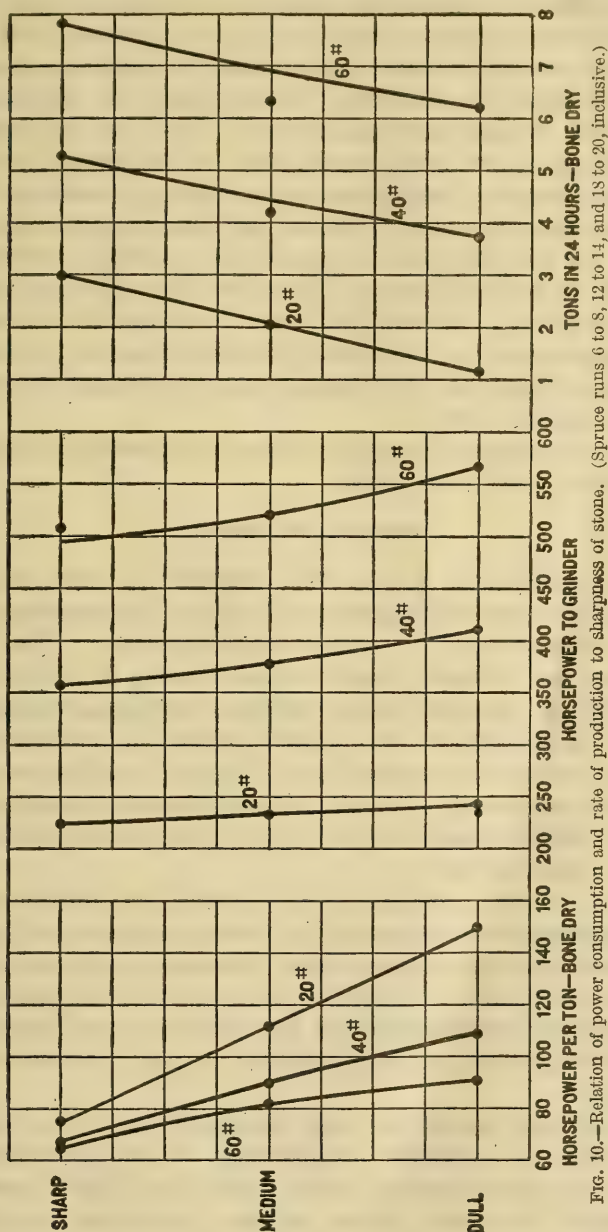


FIG. 10.—Relation of power consumption and rate of production to sharpness of stone. (Spruce runs 6 to 8, 12 to 14, and 18 to 20, inclusive.)

The fibers in Plate II, figure 1, were produced on a stone having a degree of sharpness between the above two, and those shown in figure 2 were obtained on a sharp, coarse grit stone.

GRIT OF STONE.

If a stone of coarse grit is used considerably less dressing with the burr is necessary to attain the conditions of a sharp stone. In fact, it is difficult to produce a pulp that is not coarse and full of shives. Although a somewhat lower consumption of power per ton of pulp is easily obtained, on account of its coarseness the pulp is not satisfactory from a news-print standpoint. The yield of screenings is much greater, as one would anticipate. As indicated by the Mullen tester, the strength of pulp ground on a coarse grit stone is a trifle less than when made on a finer grit stone and consuming the same amount of power per ton; but when compared as to their respective breaking lengths, there is no difference. However, when the wood is steamed prior to grinding, a strong pulp may be obtained at lower horsepower consumption on the coarse grit stone than on a finer one. A comparison of the grits of the stones may be obtained by referring to Plate III, figures 1 and 2.

In general, a stone of fine grit yields a fine-fibered pulp and a coarse stone a shivy and coarse pulp.

PRESSURE OF GRINDING.

In any commercial grinder the pressure at which the wood is forced upon the revolving grindstone—that is, the pressure per square inch of wood surface in contact—varies greatly. The variations in pressure are brought about by the binding of the wood in the pockets; the grinding of wood of different lengths and diameters; the variation of pressure on the grinder cylinder, due to the removal of pressure from one or more of the cylinders, and the use of varying amounts of split wood. For any cylinder pressure, however, it is reasonable to assume that the pressure per square inch on the stone varies between certain limits.

Figure 11 shows the relation of the pressure on the grinder cylinder, the horsepower consumption per ton, power to grinder, and production in 24 hours, the three curves being obtained on surfaces of different degrees of sharpness. It will be noted that with increasing pressure the horsepower consumption per ton decreases, and that the horsepower to the grinder and production in 24 hours increases at a fairly definite rate.

The yield and quality of pulp produced vary to a considerable degree with the pressure of grinding. Finer, although shorter-fibered, pulps are obtained when grinding at higher pressure, the advantage of the use of higher pressure being that it is possible to use a duller stone and obtain finer-fibered pulp with a consumption of the same amount of power as would be used at lower pressure and sharper condition of the stone.



FIG. 1.—SPRUCE MECHANICAL PULP (RUN No. 11).

F-LAB. 4



FIG. 2.—SPRUCE MECHANICAL PULP (RUN No. 5).

F-LAB. 5



FIG. 1.—SPRUCE MECHANICAL PULP (RUN NO. 17).

F-LAB. 6

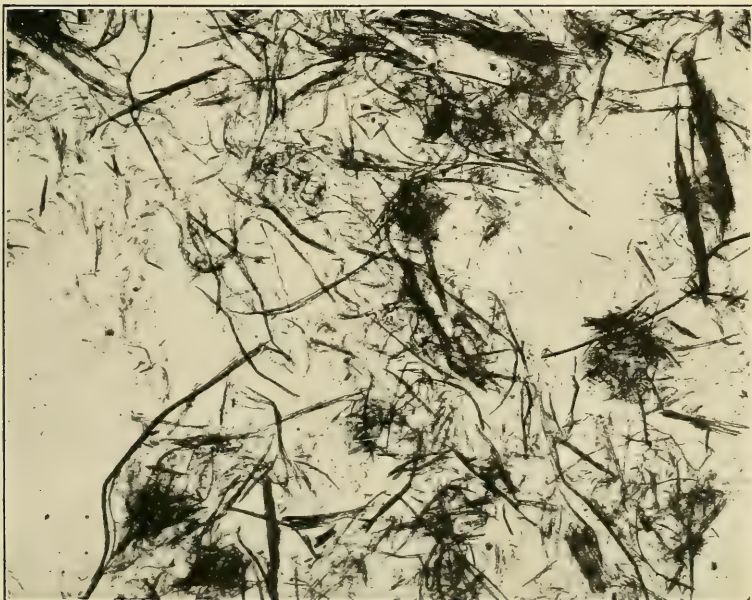


FIG. 2.—SPRUCE MECHANICAL PULP (RUN NO. 275).

F-LAB. 7



FIG. 1.—MEDIUM GRIT PULPSTONE.

F-LAB. 8

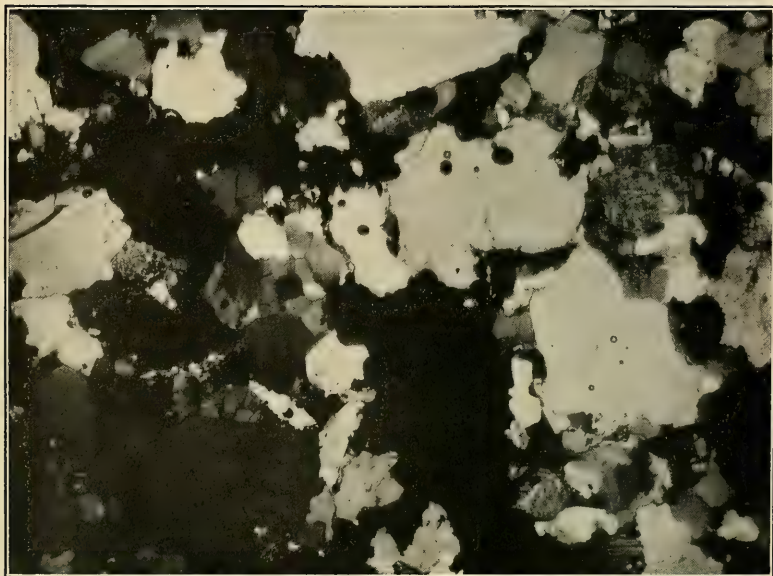


FIG. 2.—COARSE GRIT PULPSTONE.

F-LAB. 9

Figure 12 shows the effect of increasing pressure on the yield per 100 cubic feet of solid rossed wood. There is a material increase in

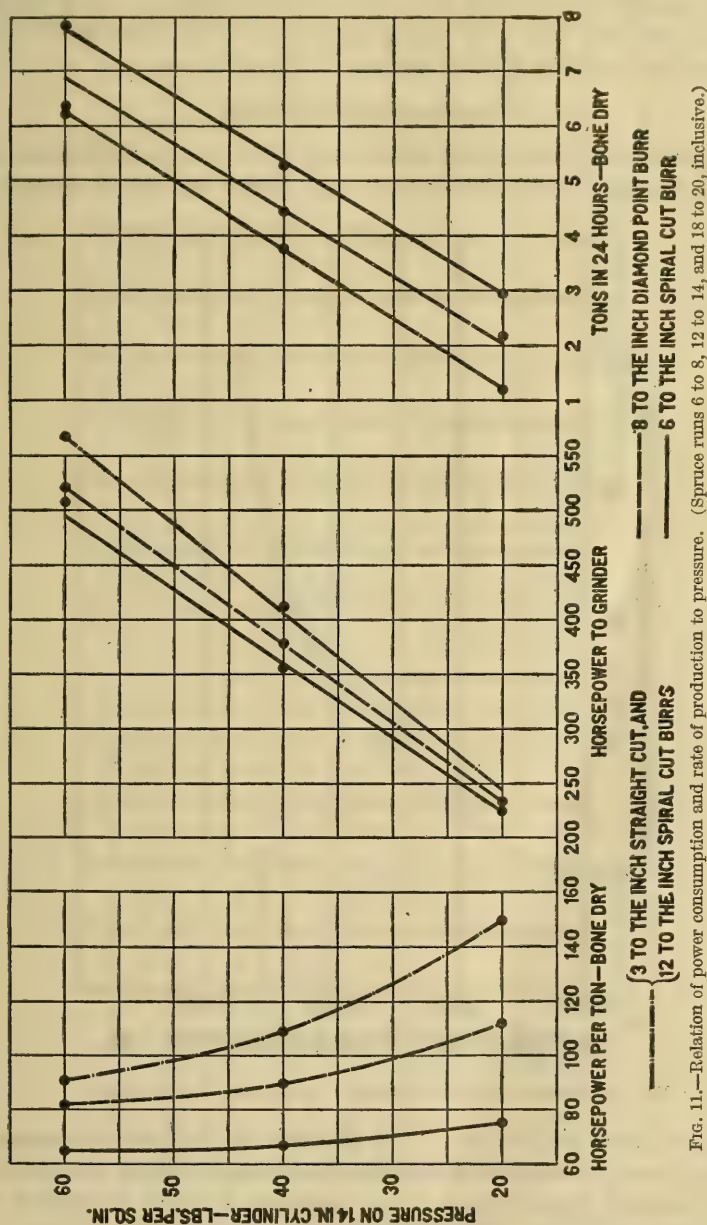


Fig. 11.—Relation of power consumption and rate of production to pressure. (Spruce runs 6 to 8, 12 to 14, and 18 to 20, inclusive.)

the amount of pulp produced from this quantity of wood if the pressure of grinding is increased from 20 pounds per square inch on a 14-inch cylinder to 100 pounds.

The effect of pressure on the quality of pulp as indicated by the strength of paper made from it is shown in figure 13. The strength factor, or bursting strength per square inch divided by the weight per ream, decreased with increasing pressure. The decrease in power consumption per ton is also shown.

PERIPHERAL SPEED OF STONE.

In figure 14 is shown the variation of the horsepower consumption per ton, horsepower to the grinder, and production in 24 hours, with

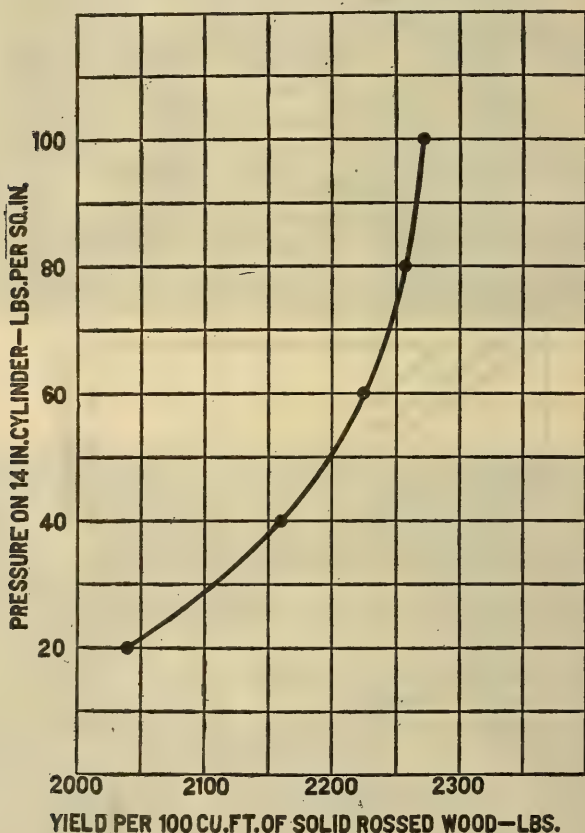


FIG. 12.—Relation of yield to pressure. (Spruce runs 52 to 56, inclusive.)

varying speed of pulp stone. The decrease in the power consumption per ton from 100 to 250 revolutions per minute when steamed wood is used is much greater than when unsteamed wood is ground under the same conditions. (See fig. 15.)

The pressure at which wood is steamed prior to grinding has a marked influence on the speed of rotation of the pulp stone necessary to consume a certain amount of power when the grinding pressure is maintained constant. This is shown in figure 16. The wood was

steamed at varying pressures for periods of three and six hours and then ground in two pockets of the grinder at a cylinder pressure of 60 pounds per square inch. The power to the grinder was maintained at 345 horsepower, and it was utilized by adjusting the periph-

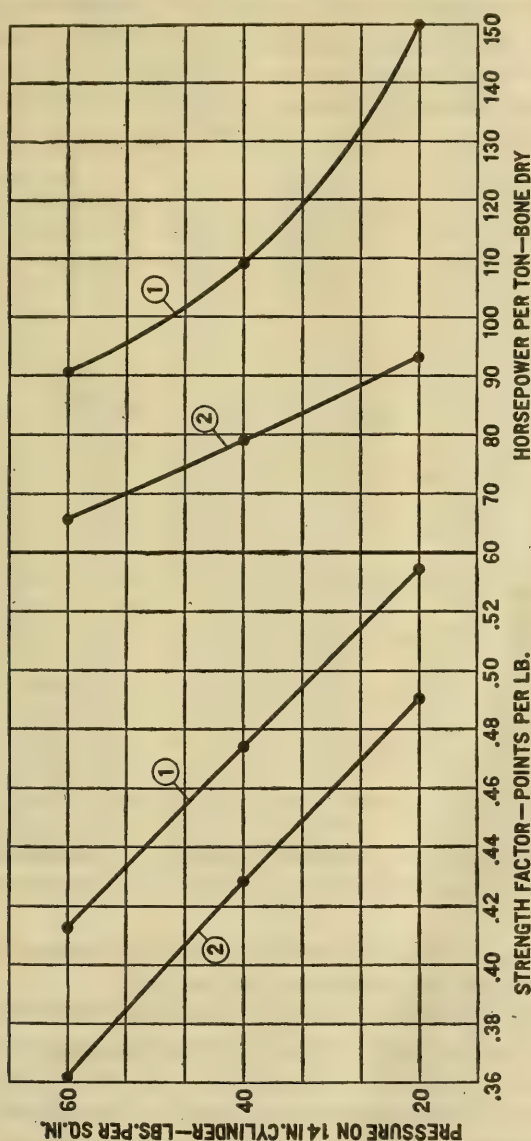


FIG. 13.—Relation of strength of paper and power consumption to pressure. (1) Spruce runs 9-1 to 11 and (2) 6 to 8, inclusive.

eral speed of the stone to such a value as was necessary for the sample being tested. When wood which had been steamed for 6 hours at 75 pounds pressure was ground a cylinder pressure of 60 pounds on two pockets and speed of 225 revolutions per minute were necessary

to consume the 345 horsepower. When the wood was steamed for 6 hours at 20 pounds, a cylinder pressure of 60 pounds and speed of 187 revolutions per minute were necessary to use up the power.

There are shown in figure 17 the relation of horsepower consumption per ton, horsepower to the grinder, and production in 24 hours to the steaming pressure when wood, which had been cooked at different pressures, was ground at constant cylinder pressure and varying speed of rotation of the pulp stone. It will be noted that the horsepower consumption per ton increases with the speed, corresponding

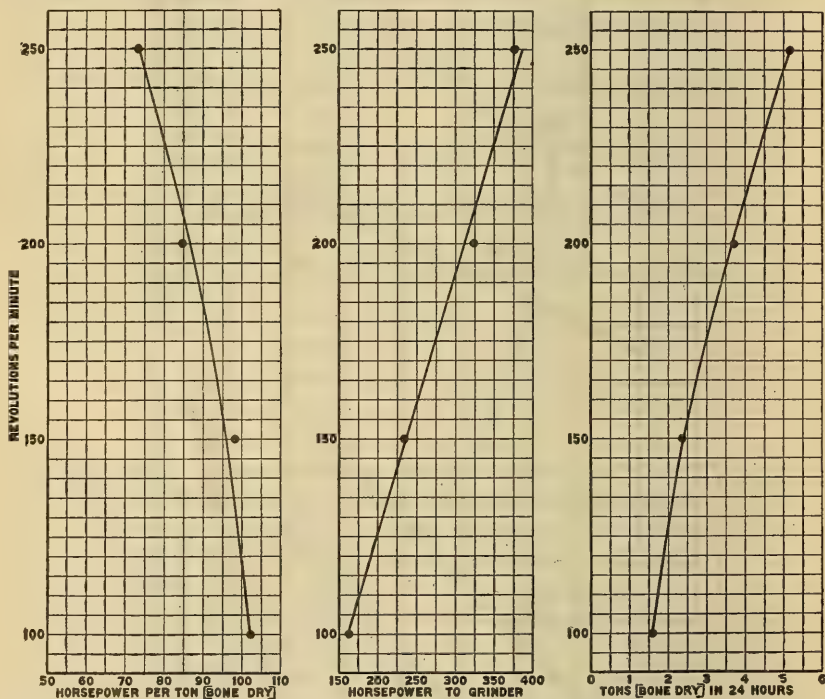


FIG. 14.—Relation of power consumption and rate of production to speed. (Spruce runs 188 to 191, inclusive.)

to increase in the pressure of steaming, and this increase is due to a reduction in the rate of production of the pulp.

When wood is steamed for a certain number of hours and at a fixed pressure, then ground with a certain amount of power to the grinder but under varying speed of rotation of the pulp stone, it is found that the horsepower consumption per ton increases in a similar manner to that given in figure 18. In other words, at low speed and high pressure more power is necessary to grind a ton of pulp in 24 hours than at high speed and low pressure. This is due, again, to the reduction in the rate of production.

The peripheral speed of the pulp stone influences the power consumption only slightly. The power consumption per ton decreases somewhat when the speed is increased (fig. 15). It is also shown that

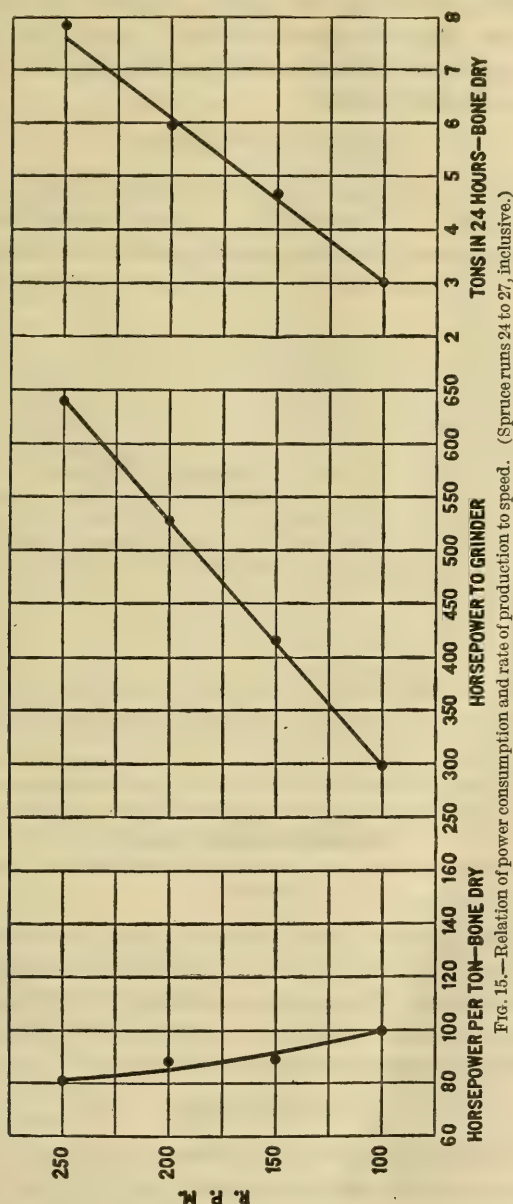


FIG. 15.—Relation of power consumption and rate of production to speed. (Spruce runs 24 to 27, inclusive.)

the horsepower to the grinder and production in 24 hours increase directly with the speed of the pulp stone. The speed has much less effect upon the quality of the pulp than either the pressure or surface

of the stone. Stronger pulp is obtained, however, at conditions of low speed and high pressure than is obtained at conditions of high speed and low pressure. It is believed, however, that the pressure is more responsible here than the speed. Figure 19 shows that the strength of paper, when the same amount of power is applied, is much less when the power is utilized at high speed and low pressure than at high pressure and low speed.

TEMPERATURE OF GRINDING.

There has always been more or less discussion about the effect of grinding hot or cold. Throughout the experimental work discussed little influence has been noted in grinding under conditions of varying temperature. It is true that the production in 24 hours is less when

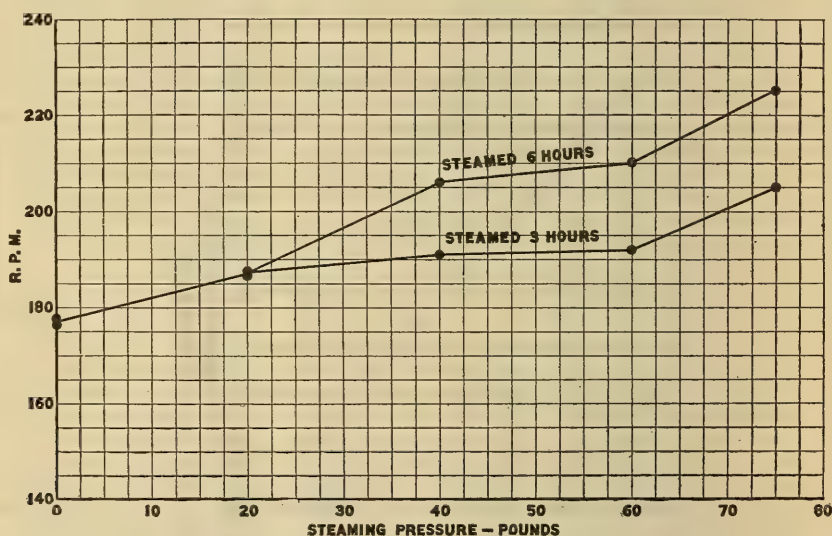


FIG. 16.—Effect of steaming pressure on speed—horsepower to grinder constant. (Spruce runs 233 to 242, inclusive.)

grinding cold than when the hot process is used, but the variation of the temperature from 125° to 190° F. does not materially influence the rate of production. The pulp is somewhat finer when ground cold, but there is not as much difference between pulps manufactured by the cold and hot processes as is generally believed.

OTHER FACTORS.

Among the other factors which influence the power consumption, production in 24 hours, and the quality and yield of pulp are the amount of seasoning the wood has undergone before grinding, the dry weight per cubic foot, the size of bolts, and the rate of growth.

It is easier to grind green wood and secure a satisfactory pulp than it is to grind seasoned wood. Seasoned wood almost invariably

yields a shorter fibered pulp, with a color inferior to that obtained from the green material. Green wood likewise requires less power to grind it, although the difference in the power consumption per ton between that obtained from green and seasoned wood is very small.

The weight per cubic foot of wood is a most important factor, since upon it depends almost entirely the yield per cord. This is best shown in figure 20, where the dry weights of a number of different species are plotted against the yield of pulp per 100 cubic feet of solid rossed wood. It has been found that the yield is almost directly proportional to the bone-dry weight per cubic foot.

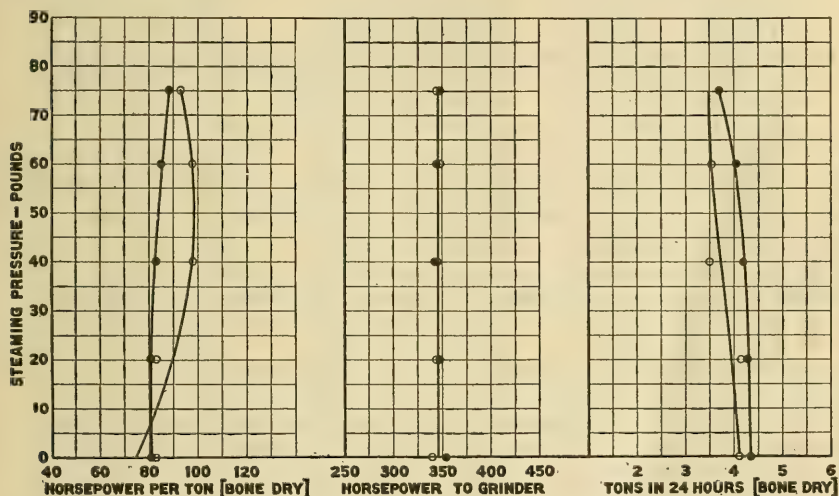


FIG. 17.—Relation of power consumption and production to steaming pressure—horsepower to grinder constant. (Spruce runs 233 to 242, inclusive.)

The following is a list of woods corresponding to the numbers shown on the curves in figure 20:

- No. 1. Balsam fir.
- 2. Red fir.
- 3. White fir.
- 4. Alpine fir.
- 5. Amabilis fir.
- 6. Lowland fir.
- 7. Noble fir.
- 8. Eastern hemlock.
- 9. Western hemlock.
- 10. Tamarack.
- 11. Western larch.
- 12. Montana lodgepole pine.
- 13. California lodgepole pine.

- No. 14. Western yellow pine.
- 15. Jack pine.
- 16. Loblolly pine (fall cut).
- 17. Loblolly pine (spring cut).
- 18. White pine.
- 19. Engelmann spruce (Montana).
- 20. Engelmann spruce (Colorado).
- 21. Sitka spruce.
- 22. White spruce.
- 23. White birch.
- 24. Aspen.¹
- 25. Black gum.

¹ Commonly called "popple" in Wisconsin.

The rate of growth seems to have little effect upon the power consumption or rate of production. When the wood is of large diameter it is necessary to split a considerable portion of it and more or less binding is caused, this resulting in a higher power consumption per ton of pulp. The yield and quality are both slightly influenced by the rate of growth of the wood. The yield is lower from wood of rapid growth than from wood which has grown slowly. The pulp is softer when rapid-growth wood is used, although the strength is practically the same. Generally woods which are highly lignified

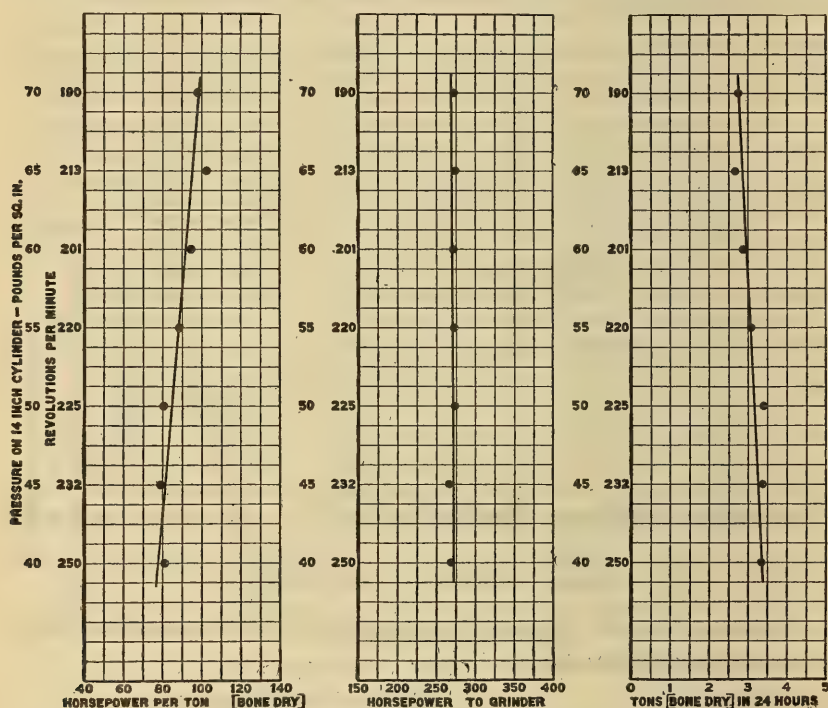


FIG. 18.—Relation of power consumption and production to pressure and speed—horsepower to grinder constant. (Tamarack runs 62 to 68, inclusive.)

yield shorter fibered pulps than those having large amounts of sapwood.

The condition of the wood as regards decay has a marked effect on the pulp. With the use of partially decayed wood the yield of pulp from a cord is greatly decreased, and while the wood grinds faster than entirely sound wood, giving an increased production and a correspondingly lower power consumption per ton of pulp, the pulp consists principally of extremely short fibers and wood flour, which greatly decrease its strength. (Spruce runs 255 and 256.) At the same time the color is materially darker than that of the pulp produced from sound wood.

POWER CONSUMPTION PER UNIT OF STRENGTH.

It has always been known that the consumption of a great amount of power will produce pulp of a greater strength. The relative effect, however, in using different amounts of power is probably best shown in figure 21. The strength as represented by Mullen or Schopper tests increases with increasing power consumption per ton.

Figure 22, curve *A*, shows the relation between horsepower consumption per ton of pulp per meter of breaking length of paper made

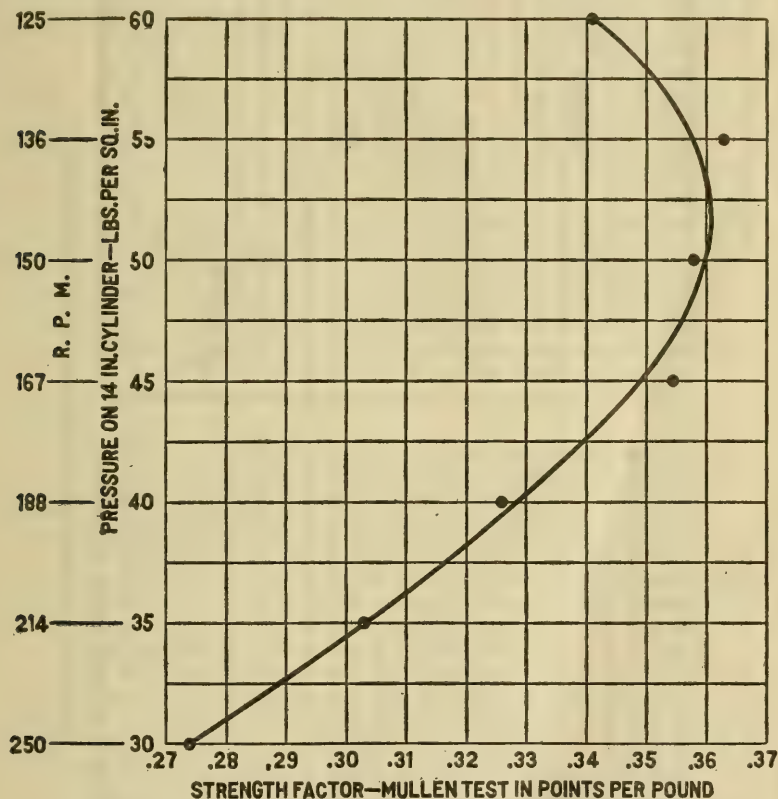


FIG. 19.—Relation of strength of paper to pressure and speed. (Spruce runs 32 to 38, inclusive.)

from it, and the power consumption in grinding a ton of the pulp. At low values of power consumption greater strength is produced per horsepower than at high values. The horsepower per ton per point per pound is also shown in the same figure, curve *B*.

STEAMED WOOD PULP AND ITS USES.

The pulp made by grinding steamed wood can be used for different purposes, depending largely upon the nature of the grinding process. If a sharp and coarse stone is used a large number of shives will be present and the pulp will serve for the manufacture of box board or

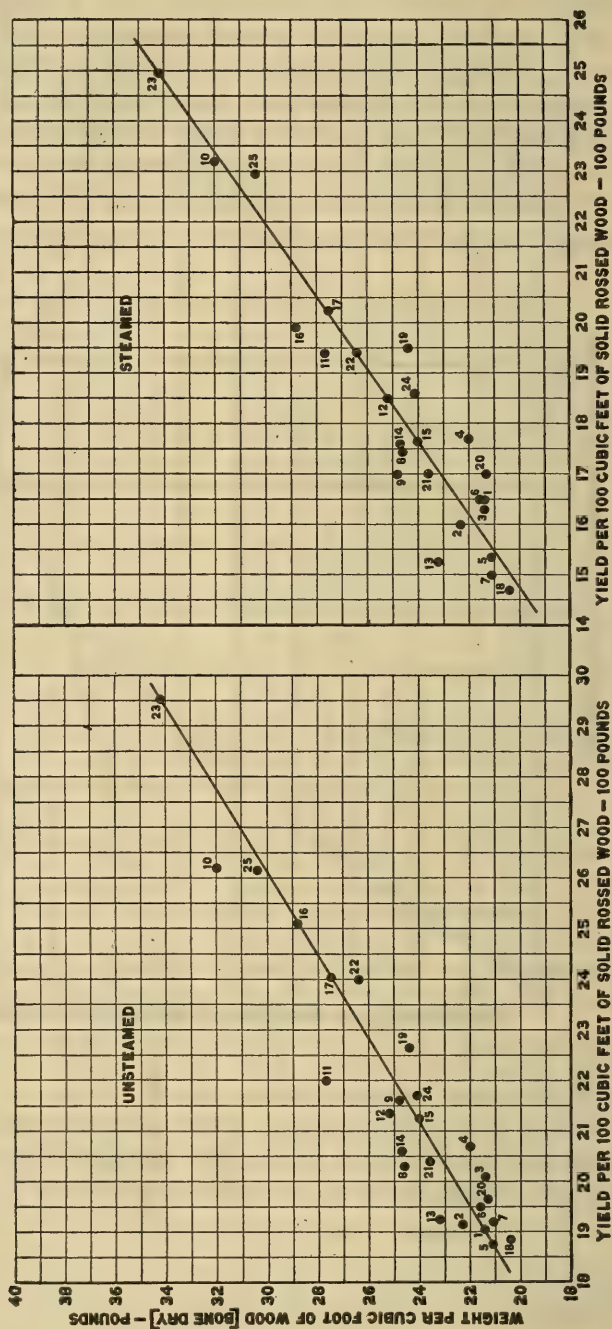


FIG. 20.—Relation of yield to dry weight of wood—steamed and unsteamed.

similar materials. When ground to a finer state, however, it has been demonstrated that with a mixture of a small amount of chemical fiber bogus kraft paper can be produced which will serve for a cheap

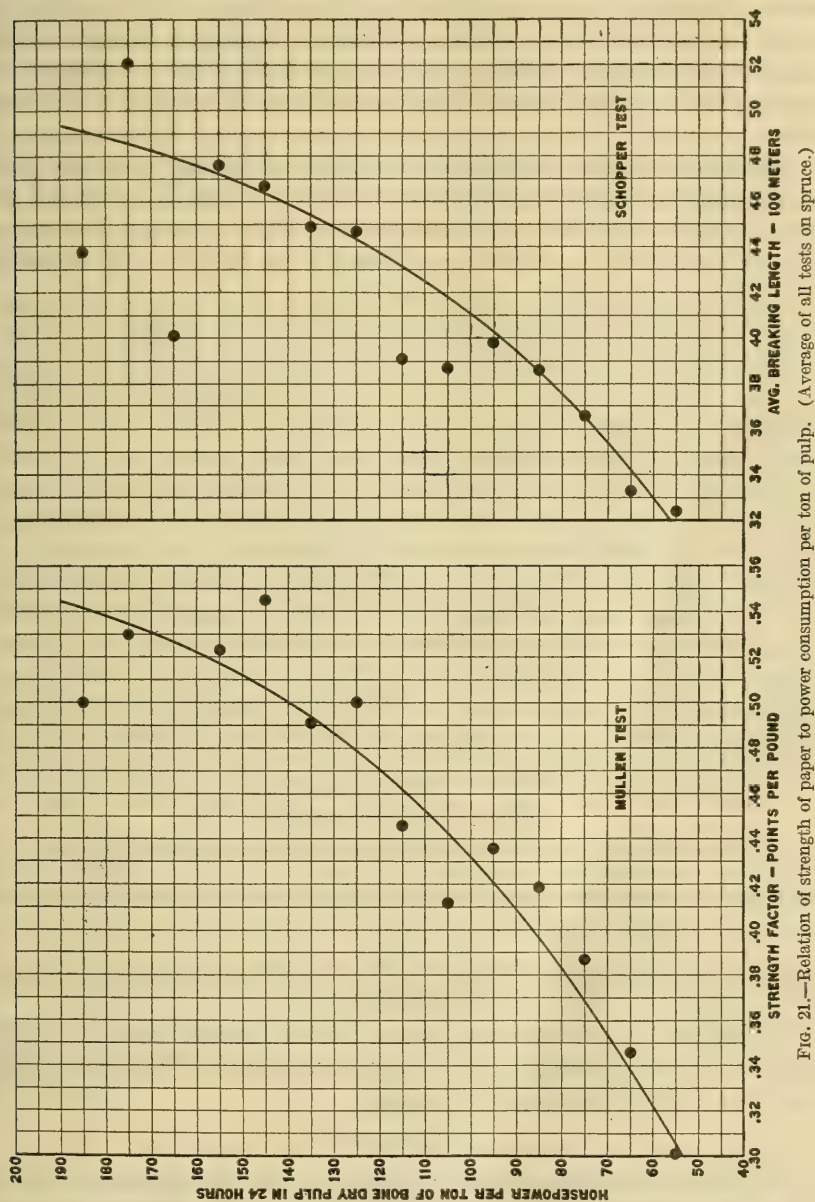


FIG. 21.—Relation of strength of paper to power consumption per ton of pulp. (Average of all tests on spruce.)

wrapping paper. It is hardly likely that spruce could be used for the manufacture of cheap wrapping paper in this manner on account of its price, but other woods, which will be discussed later, also give

remarkably good results, and, being available in large quantities, should serve as a raw material for this purpose. Tests made on sheets composed entirely of boiled and steamed ground-wood pulp show that wrapping papers which will test from 0.50 to 0.75 of a point to the pound are easily produced. Wrapping papers of this kind are inclined to be brittle and do not have sufficient strength in tearing or folding without the addition of a small amount of chemical fiber.

Resinous woods, if given a mild steaming or boiling treatment prior to grinding, are rendered much more free from pitch, although the pulp is made very soft and darkened to some extent. The use of this method for the production of news print paper would undoubt-

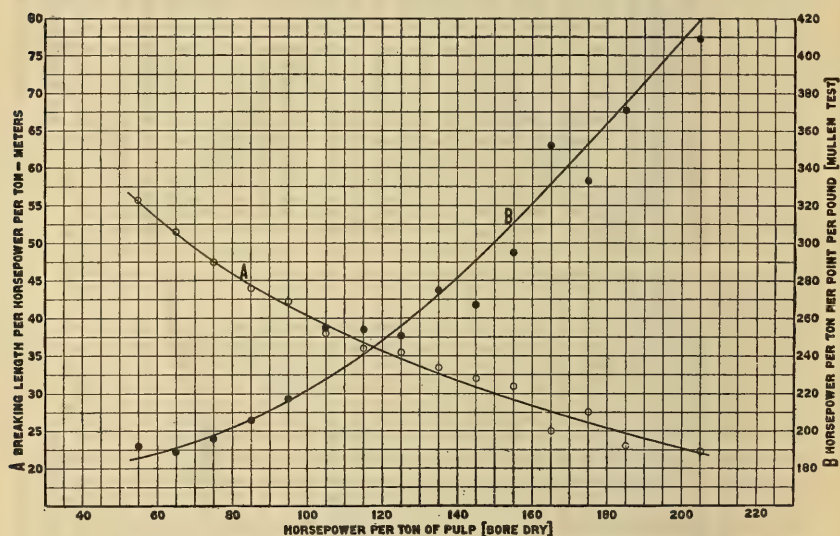


FIG. 22.—Relation of strength of paper per horsepower to power consumption per ton of pulp.

edly be costly on account of the handling necessary, the cost of steaming, and the loss in yield.

SUMMARY OF INFLUENCE OF GRINDING AND COOKING CONDITIONS IN THE PRODUCTION OF SPRUCE PULP.

The experiments conducted by the Forest Service, both in cooking spruce prior to grinding and in varying conditions of producing pulp, have led to the following conclusions:

COOKED WOOD.

(1) Cooking spruce prior to grinding results in a stronger fibered pulp, although at least 25 per cent more power per ton is required than is used in grinding untreated wood. The horsepower consumption per ton when grinding under conditions of varying cylinder pressure decreases to a minimum at approximately 65 pounds pressure on a 14-inch cylinder; this holds for dull or sharp stones.

(2) When wood is cooked under conditions of constant pressure and varying lengths of time the maximum power consumption per ton of pulp is obtained after cooking for six hours. This holds true regardless of the pressure at which the cooking takes place, between 0 and 75 pounds gauge pressure.

(3) Wood which is cooked at high pressure requires more power per ton of pulp when ground under the same conditions of cylinder pressure, speed, and surface of stone than wood which is cooked at lower pressure, if the duration of the cook is the same. Likewise, the production of pulp in 24 hours is materially less when the wood ground has been cooked at high pressure than if it had been cooked at low pressure.

(4) The yield per cord is influenced very greatly by the length of time the cooking is carried on and the pressure of the cook, being much lower for high pressures than for low and also for long cooking periods than for short.

(5) The power to the grinder increases with speed and pressure of grinding and decreases with the degree of sharpness of stone. There is also a very slight increase in the power required with increase of temperature, other conditions remaining constant, while the thickness of stock in the grinder pit has almost no influence. Under like conditions of all other factors the power to the grinder is less for steamed wood than for green or seasoned wood untreated.

(6) With a fixed amount of power to the grinder and a fixed grinding pressure, the speed of the pulp stone will vary greatly, depending on the length of time the wood has been steamed and the steaming pressure. Unsteamed wood will grind at low speed, while that steamed a long time will grind at high speed with the same amount of power to the grinder.

(7) There is little if any difference in the quality of pulp obtained as a result of using either the boiling or steaming process. The color, length of fiber, and yield are practically the same if the boiling or steaming is carried on at the same temperature.

(8) The amount of pulp produced in grinding cooked wood with a fixed amount of power to the grinder is less at high pressure and low speed than it is at low pressure and high speed. This results in a greater horsepower consumption per ton of pulp at high pressure and low speed.

UNCOOKED WOOD.

(1) The rate of production varies directly with pressure, speed, and degree of sharpness of stone. Less pulp is obtained in 24 hours using seasoned wood than with green, and still less using steamed wood, all other conditions being the same. The temperature influences the rate of production to some extent; less pulp is produced at low temperatures.

(2) The horsepower consumption per ton of pulp when untreated wood is ground increases as the pressure decreases according to a fairly definite law; it is lower on sharp stones than on dull ones, and increases as the speed decreases in much the same manner as it does with pressure. There is, however, not as much difference between the power consumption per ton at low speed and high speed as there is between power consumption at low pressure and high pressure. The power consumption is very little influenced by temperature, but it is slightly lower at high temperature. The power consumption is higher for seasoned wood than for green wood, and higher for steamed wood than for either seasoned or green material ground under the same conditions.

(3) The yield of pulp per cord is greater at high pressure than at low, and, while this is true also of the screenings, there is not as much fine material lost in white water when high pressure is used. The yield is not greatly influenced by the surface of the stone, but is slightly higher at high speed than at low. The yield is proportional to the bone-dry weight per cubic foot of wood.

(4) The quality of pulp varies greatly with the surface of the stone, less with the pressure, and least with the speed. The weight per cubic foot and character of wood influence quality to a marked extent, especially the latter; temperature also has a marked influence; pulp of greater strength is obtained at higher temperature; pulp produced at low temperature will take a better finish. Pulp of better color can be obtained from green wood than from seasoned, and stronger pulp can be obtained by cooking the wood prior to grinding. The quality of paper manufactured under exactly the same conditions, but made of pulp produced at different grinder pressures, varies greatly with the grinder pressure and the horsepower consumption per ton of pulp. Mechanical pulp of greatest strength can be produced only by the expenditure of a relatively large amount of power.

PART II.—SUBSTITUTES FOR SPRUCE IN THE MANUFACTURE OF GROUND-WOOD PULP.

EXPERIMENTAL AND COMMERCIAL TESTS ON VARIOUS WOODS.

Grinding tests of 22 different woods were made at the Wausau laboratory. Samples of the experimental pulps were sent to the Madison laboratory for tests to determine their quality. The experimental apparatus and the methods of operation were the same as those used in the case of spruce and described in Forest Service Bulletin 127.

In addition to the experimental tests, "commercial" tests were made of the production of pulp and of the manufacture of paper. The methods employed in the preparation of the wood and the production of pulp were identical with those in the qualitative and quantitative

tests, except that more wood was employed and more pulp produced. As a rule, 2.5 tons of bone-dry pulp were manufactured during each test, though in some cases 5 tons were made. Data were recorded on power consumption, rate of production, yield, etc., and as soon as practicable the pulp was shipped to mills in the vicinity of Wausau to be made into paper. The aim in making the paper was to produce as good a grade of news print as possible from the experimental pulps under the standard mill practice of the company to which the pulps were sent. The one divergence from this practice was in the treatment of the pulp in the beater, as in some cases different amounts and kinds of color had to be added to secure the best results. The amount of size, alum, loading, color, etc., was recorded for each beater of pulp, as also were the amounts of sulphite and ground wood used. The size of screen slots, speed of machine, width of wire, etc., were also recorded.

The paper produced from the experimental pulps was given a practical try out on the presses of the New York Herald and the St. Louis Republic. The tests were conducted under the ordinary operating conditions of the pressrooms of the two newspapers. The color of the different papers varied considerably, but this was not assumed to detract from their value for news-print purposes within certain limits. Record was made of the amount of waste, the number and causes of breaks, and the number of papers run from a given quantity of material. Observations were also made on the general operating conditions and the appearance of the sheet when printed. Judgment of these latter factors was left very largely to the practical pressmen.

KINDS OF WOOD TESTED.

The woods tested to determine their suitability for mechanical pulp were as follows:

Balsam fir (<i>Abies balsamea</i>).	Western yellow pine (<i>Pinus ponderosa</i>).
Red fir (<i>Abies magnifica</i>).	Jack pine (<i>Pinus divaricata</i>).
White fir (<i>Abies concolor</i>).	Loblolly pine (<i>Pinus taeda</i>).
Alpine fir (<i>Abies lasiocarpa</i>).	White pine (<i>Pinus strobus</i>).
Amabilis fir (<i>Abies amabilis</i>).	Engelmann spruce, Montana (<i>Picea engelmanni</i>).
Lowland fir (<i>Abies grandis</i>).	Engelmann spruce, Colorado (<i>Picea engelmanni</i>).
Noble fir (<i>Abies nobilis</i>).	Sitka spruce (<i>Picea sitchensis</i>).
Eastern hemlock (<i>Tsuga canadensis</i>).	White spruce (<i>Picea canadensis</i>).
Western hemlock (<i>Tsuga heterophylla</i>).	White birch (<i>Betula papyrifera</i>).
Tamarack (<i>Larix laricina</i>).	Aspen ¹ (<i>Populus tremuloides</i>).
Western larch (<i>Larix occidentalis</i>).	Black gum (<i>Nyssa sylvatica</i>).
Lodgepole pine, Montana (<i>Pinus murayana</i>).	
Lodgepole pine, California (<i>Pinus murayana</i>).	

¹ Called "popple" in Wisconsin.

TABLE 1.—Amounts of different species used and where cut.

Kind of wood.	Ship- ment No.	Amount used.	State where grown.	County where grown.	Remarks.
		Cords.			
Tamarack (<i>Larix laricina</i>).....	1	15	Wis...	Lincoln.....	Swampy land, close stand.
Do.....	2	15	do.....	do.....	Do.
Jack pine (<i>Pinus divaricata</i>)....	3	15	do.....	do.....	Side hill, sloping south and east, sandy soil, close stand.
Do.....	4	15	do.....	do.....	Swampy land, close stand.
Do.....	5	15	do.....	do.....	Side hill, sloping south and east, sandy soil, close stand.
White spruce (<i>Picea cana- densis</i>).....	6	8	do.....	do.....	No further description.
Hemlock (<i>Tsuga canadensis</i>)..	6	8	do.....	do.....	Do.
Jack pine (<i>Pinus divaricata</i>)....	7	15	do.....	do.....	Side hill, sloping south and east, sandy soil, close stand.
Do.....	8	10	do.....	do.....	Stock of Grand Rapids Paper Co.
Hemlock (<i>Tsuga canadensis</i>)..	9	10	Mich..	.....	.....
Balsam fir (<i>Abies balsamea</i>)...	9	2	do.....	.....	.....
White spruce (<i>Picea cana- densis</i>).....	9	4	do.....	.....	.....
Do.....	10	20	Wis...	.....	Stock of Marathon Paper Mills Co.
Hemlock (<i>Tsuga canadensis</i>)..	11	16	do.....	.....	Do.
Do.....	12	18	do.....	.....	Stock of Nekoosa-Edwards Paper Co.
Lodgepole pine (<i>Pinus mur- rayana</i>).....	13	15	Mont.	Deerlodge....	Slope south, 7,000 feet eleva- tion, clay soil.
Western yellow pine (<i>Pinus ponderosa</i>).....	14	16	do.....	Missoula....	Elevation 3,500 feet, glacial loam soil.
Red fir (<i>Abies magnifica</i>).....	15	8	Cal...	Nevada.....	Stock of Floriston Pulp & Paper Co.
Lodgepole pine (<i>Pinus mur- rayana</i>).....	16	7	do.....	do.....	Do.
Western larch (<i>Larix occi- dentalis</i>).....	16	12	Mont..	Lincoln.....	Elevation 3,100 feet, heavy forest, dry, deep clay soil.
White spruce (<i>Picea cana- densis</i>).....	17	8	Wis...	Price.....	Stock of Nekoosa-Edwards Paper Co.
Balsam fir (<i>Abies balsamea</i>)...	17	8	do.....	do.....	Do.
White spruce (<i>Picea cana- densis</i>).....	18	18	do.....	do.....	Do.
Aspen (<i>Populus tremuloides</i>)...	19	8	do.....	do.....	No other data available.
White birch (<i>Betula papy- rifera</i>).....	19	11	do.....	do.....	Do.
White spruce (<i>Picea cana- densis</i>).....	20	16	do.....	do.....	Stock of Nekoosa-Edwards Paper Co.
Western hemlock (<i>Tsuga heterophylla</i>).....	21	8	Wash	Chehalis....	Aberdeen Chamber of Com- merce.
Sitka spruce (<i>Picea sitchensis</i>)..	21	8	do.....	do.....	Do.
White spruce (<i>Picea cana- densis</i>).....	22	18	Wis...	Price.....	Stock of Nekoosa-Edwards Paper Co.
Lodgepole pine (<i>Pinus mur- rayana</i>).....	23	9	Cal...	.....	Stock of Floriston Pulp & Paper Co.
Red fir (<i>Abies magnifica</i>).....	23	9	do.....	do.....	Do.
White spruce (<i>Picea cana- densis</i>).....	24	15	Wis...	Price.....	Stock of Nekoosa-Edwards Paper Co.
Balsam fir (<i>Abies balsamea</i>)...	25	8	do.....	do.....	Do.
White pine (<i>Pinus strobus</i>).....	25	8	do.....	do.....	Do.
Engelmann spruce (<i>Picea engelmanni</i>).....	26	6	Colo..	(Cochetopa Nat. For.)	Elevation 9,200 feet, deep black soil.
White fir (<i>Abies concolor</i>).....	27	17	Cal...	Plumas.....	Elevation 3,220 feet, red clay and shale soil.
Amabilis fir (<i>Abies amabilis</i>)..	28	8	Wash.	Whitcom....	Elevation 2,150, fragmentary rock soil.
Lowland fir (<i>Abies grandis</i>)....	29	5½	Mont..	Missoula....	Elevation 3,400 feet, sandy loam.
Alpine fir (<i>Abies lasiocarpa</i>)....	29	6	do.....	do.....	Elevation 3,300 feet, sandy loam.
Engelmann spruce (<i>Picea engelmanni</i>).....	29	5	do.....	do.....	Elevation 3,300 feet, gravelly loam.
White spruce (<i>Picea cana- densis</i>).....	30	10	.....	.....	Stock of Nekoosa-Edwards Paper Co.
Loblolly pine (<i>Pinus taeda</i>)....	31	6	N. C...	.....	Stock of Beaver Co., Weldon, N. C.
Black gum (<i>Nyssa sylvatica</i>)...	32	5	La....	Winn.....	Hardwood bottoms.
Tamarack (partially decayed)...	33	½	.....	.....	Selected from culls of stock of Marathon Paper Mills Co.
Noble fir (<i>Abies nobilis</i>).....	34	6	Oreg..	Multnomah..	Elevation 3,500 feet, rocky soil.

The region in which the different species grow is shown on the maps, figures 23 to 44. Table 1 gives source of shipments tested. Information concerning the amount of each kind of timber available

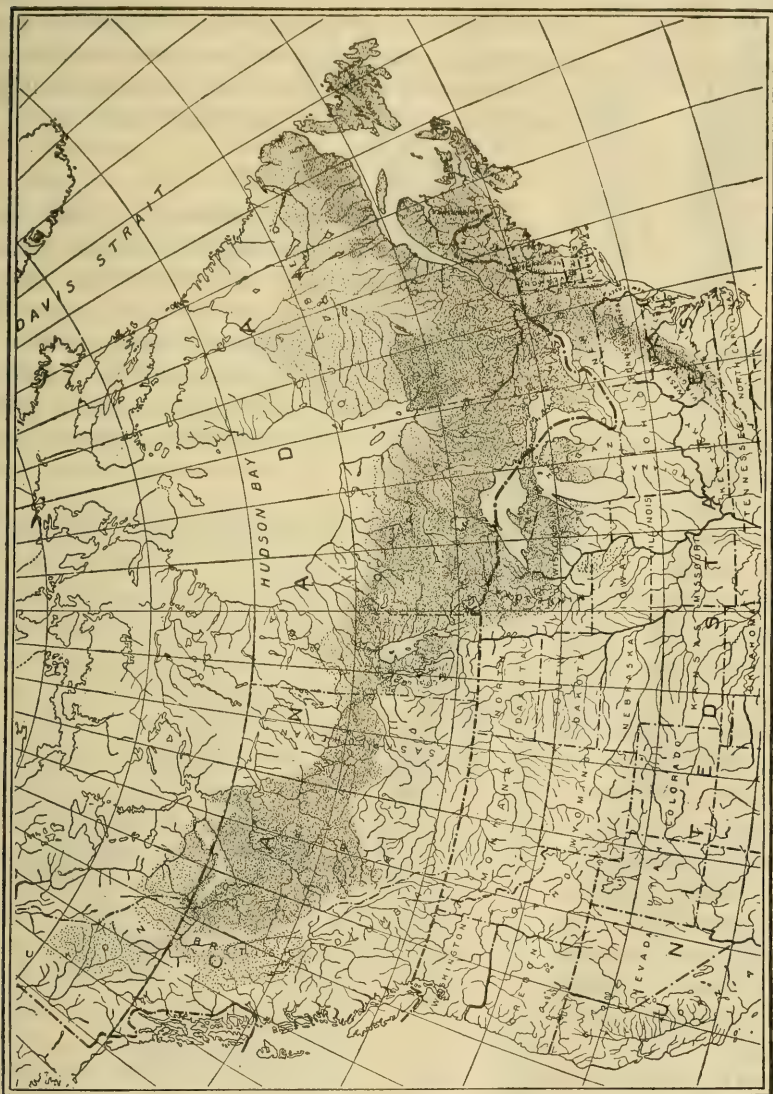


FIG. 23.—Balsam fir (*Abies balsamea*).

and other facts relating to the stand and supply will be furnished by the Forest Service upon request.

RESULTS OF GRINDING TESTS.

On the whole, very little difficulty was encountered in producing pulp from the woods tested. With the conifers, at least, grinding could be done under practically the same conditions employed for

spruce. All the substitutes, however, with the possible exception of noble fir and amabilis fir, required the use of more power per ton of pulp. Also, while a good grade of spruce pulp can be produced under widely varying conditions of grinding, the best results were generally obtained from the other woods when the stone was somewhat dull, the pressure high, and the speed of grinding rather slow.



FIG. 24.—Red fir (*Abies magnifica*).

Such pulp is as light in color as, if not lighter than, spruce, and a fairly sharp stone can be used in grinding it. Seasoned wood, however, usually shows decay and insect attack, and it is practically impossible to grind it into pulp which will not contain many shives and be somewhat soft. The yield from balsam fir is about 1,910 pounds (bone-dry pulp) per hundred cubic feet of solid rossed wood, or approximately 490 pounds less than the yield from an equal quantity of white spruce.

Red fir, like balsam, is easily ground to a pulp satisfactory for news-print purposes. It required, however, more power per ton of pulp, due possibly to the fact that the wood used in the experiments was of such a large diameter that it had to

THE FIRS.

The firs tested were balsam fir (*Abies balsamea*), red fir (*Abies magnifica*), white fir (*Abies concolor*), amabilis fir (*Abies amabilis*), alpine fir (*Abies lasiocarpa*), lowland or grand fir (*Abies grandis*), and noble fir (*Abies nobilis*).

A good sheet of pulp can easily be obtained from balsam fir if the wood is in a green state.

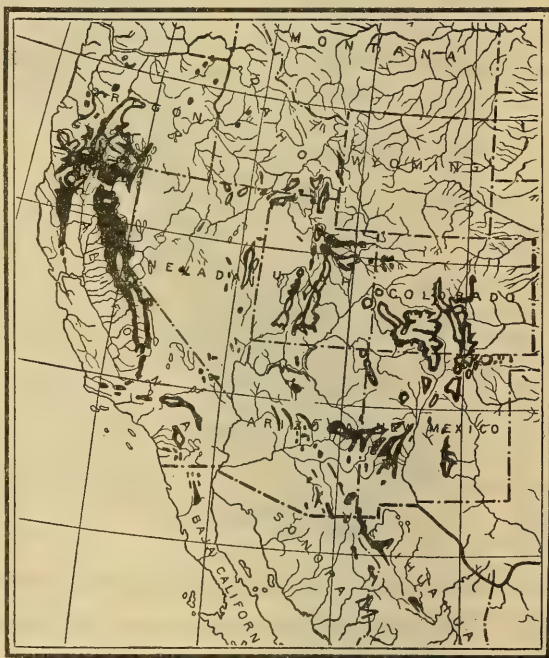


FIG. 25.—White fir (*Abies concolor*).

be split before it could be ground. The pulp had a reddish tinge, which made it less suitable for news-print purposes than that of some other woods which grow in the same region. The yield was approximately 1,915 pounds (bone dry) per hundred cubic feet of solid rossed wood, or nearly 500 pounds less than for white spruce. On the basis of a cord of rough wood the difference in yield would be even greater on account of red fir's extremely thick bark.

White fir yields a very satisfactory pulp, especially when the wood is green and comes from young trees. Tests conducted on this species, to note the influence of age of the trees on the quality of the pulp produced, showed that pulp from the split wood of trees 40 inches in diameter and 130 feet high was inferior in color, fiber, and yield to pulp obtained from trees of 18 inches in diameter or less. Pulp obtained from the older wood was inclined to be soft and shivy; that from the younger wood did not show these defects. The color of white-fir pulp is better than that of red fir, though not as good as that of balsam. White-fir

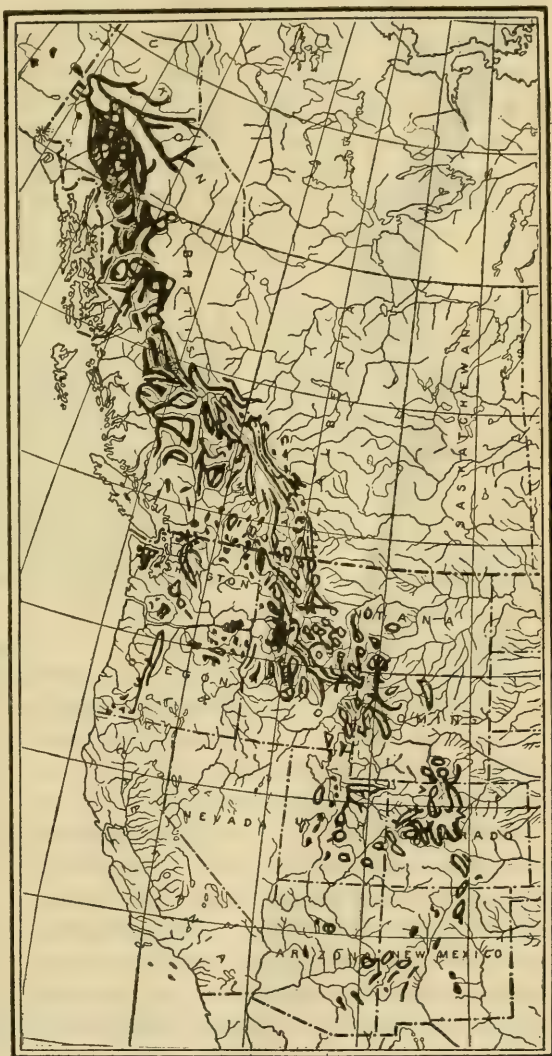


FIG. 26.—Alpine fir (*Abies lasiocarpa*).

pulp is rather soft. The yield is approximately 2,000 pounds (bone dry) per hundred cubic feet of solid rossed wood, or about 400 pounds less than white spruce.

Alpine fir yields a very good quality of pulp, which in color is as light as, if not lighter than, spruce pulp. It can be ground with a

fairly sharp stone and without an unusual expenditure of power. The result is a pulp very satisfactory for news-print purposes. The yield is approximately 2,060 pounds (bone dry) per hundred cubic feet of solid rossed wood. This wood is usually free from knots and other irregularities, and has a fairly thin, smooth bark.

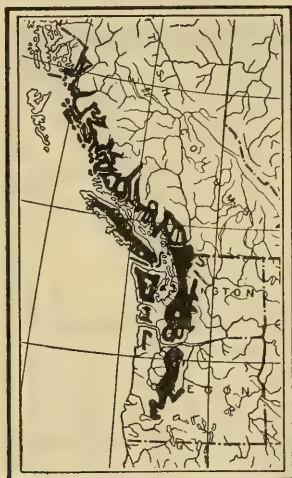


FIG. 27.—Amabilis fir (*Abies amabilis*).

Amabilis fir readily grinds to a pulp suitable for news-print purposes. The color of the pulp is slightly grayish, but an excellent fiber can be produced with a sharp stone and a reasonable amount of power. In strength the pulp is about equal to that obtained from spruce. The wood used in the tests was split from large logs having a number of good-sized knots. The yield is approximately 1,870 pounds (bone dry) per hundred cubic feet of solid rossed wood. As in the case of red fir, the thick bark of amabilis fir would result in decreasing the yield were the latter figured on the basis of a rough-piled cord.

Lowland or grand fir can be ground on a fairly sharp stone to produce pulp well adapted for news-print paper. The quality is not up to that of balsam or amabilis fir, but is better than that of white, alpine, or red fir. The pulp produced at the laboratory had a slightly grayish cast, which in some measure might be due to the heart rot that was beginning to attack many of the logs. The yield was approximately 1,950 pounds (bone dry) per hundred cubic feet of solid rossed wood.

Noble fir readily yields a pulp satisfactory for news-print purposes. Like white spruce, it can be ground with a wide variation of power consumption. The pulp has a marked pinkish tinge, which is objectionable, but the fibers are of unusual length and strength, though with a tendency to coarseness. The wood tested was supplied from a large tree freshly cut and was remarkably free from knots. The yield was approximately 1,920 pounds (bone dry) per hundred cubic feet of solid rossed wood, or about 480 pounds less than that from an equal amount of spruce.

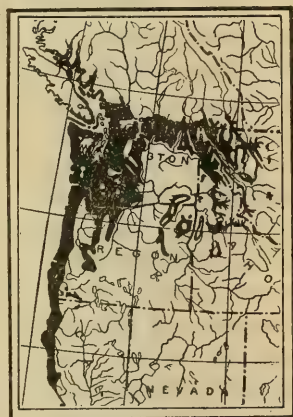


FIG. 28.—Lowland fir (*Abies grandis*).

THE HEMLOCKS.

Eastern hemlock (*Tsuga canadensis*) requires a considerable amount of power for the production of satisfactory pulp. The wood must also be of fairly small diameter and of very good quality. Even under the best conditions, eastern hemlock pulp does not present a good appearance; the fibers are short, and it has a decided reddish tinge. Moreover, it is very hard to produce pulp which will not crack along the edges when the laps are folded. However, even with the handicap of short fibers, a pulp satisfactory for news-print purposes can be produced. The yield from eastern hemlock is approximately 2,030 pounds per hundred cubic feet of solid rossed wood (370 pounds less than from an equal amount of white spruce), though the same ratio would not be evident if the basis were a cord of rough wood.

Western hemlock (*Tsuga heterophylla*) can be ground at much higher pressures and with a sharper stone than eastern hemlock. The pulp produced is of very good quality and aside from its grayish color compares well with white spruce. It is far superior to that from eastern hemlock. The yield is about 2,160 pounds per hundred cubic feet of solid rossed wood, or 240 pounds less than that from white spruce, though the bark of western hemlock is much heavier than that of the latter species.

THE LARCHES.

Tamarack (*Larix laricina*) produces a very good quality of pulp with a reasonable amount of power. In color, however, the pulp is a decidedly grayish green. It would probably serve for news-print paper if used with spruce sulphite or mixed with spruce ground wood. In any event, it could be used for wrapping paper. The yield is approximately 2,620 pounds per hundred cubic feet of solid rossed wood, or about 220 pounds more than from an equal amount of white spruce.

Western larch (*Larix occidentalis*) yields a very inferior pulp. The product is difficult to operate on the wet machine, and the pulp stone must be rough, but not sharp, to secure the best results. In other words, the pulp must have coarse fibers and a relatively large number of shives. The color, a decided brown, is objectionable. The yield from western larch was only 2,100 pounds per hundred cubic feet of solid rossed wood, though on the basis of the dry weight of the wood it should have been at least 2,300 pounds. This difference is probably due to the high proportion of the wood substance that is soluble in water and to the brittleness of the heartwood, so that a large percentage of the yield is lost in the white water.

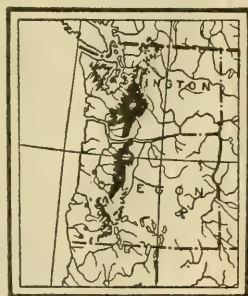


FIG. 29.—Noble fir (*Abies nobilis*).

THE PINES.

Both the California and Montana lodgepole pine (*Pinus murrayana*) yield pulp of very good quality. The wood can be ground under ordinary conditions and does not require the consumption of a large amount of power. Satisfactory results are obtained when the wood is ground at high pressures and at high speed, provided the stone is somewhat dull. The color of the pulp from both varieties compares favorably with that of white spruce, though the Montana wood is somewhat lighter than the California. The resin did not prove objectionable. Montana lodgepole pine yielded



FIG. 30.—Eastern hemlock (*Tsuga canadensis*).

approximately 2,140 pounds of pulp (bone dry) per hundred cubic feet of rossed wood, while California trees yielded about 1,920 pounds. The difference was due to the greater age, larger size, and lighter weight of the California wood.

Western yellow pine (*Pinus ponderosa*) can be ground under a wide variety of conditions. The pulp has a fairly long, coarse fiber and is invariably soft. In color it tends toward a creamy, resembling to some extent that obtained from jack pine. While the wood used in the test contained considerable pitch, this did not cause much trouble either in the grinding process or in the operation of the wet machine. The wood used was cut in October, and it is reasonable to suppose that material cut after the sap had gone down would

have been better. The fact that the majority of the tests were made after the wood had seasoned from one to one and one-half years might also account for the more satisfactory operation of the material. The yield was approximately 2,060 pounds per hundred cubic feet of solid rossed wood.



FIG 31.—Western hemlock (*Tsuga heterophylla*).

Jack pine (*Pinus divaricata*) yields a very good pulp when ground with a rather dull stone, necessitating, of course, a high power consumption. The pulp produced at a consumption of from 90 to 100 horsepower per ton for 24 hours compares favorably with white spruce pulp made with a somewhat lower power consumption. In

color jack pine is creamish or even brownish, and the pitch may cause trouble on the felts, especially if the wood is not seasoned or has not been ponded for a considerable period of time. The best results can be obtained from pitchy woods if the trees are cut when the sap is down. The yield of jack-pine pulp per hundred cubic feet of solid rossed wood was about 200 pounds less than that from an equal amount of white spruce.

Loblolly pine (*Pinus taeda*) requires a dull stone and consequently an expenditure of a large amount of power, but does not yield a pulp of as good a quality as may be obtained from the other pines



FIG. 32.—Tamarack (*Larix laricina*).

tested. Although hardly suitable for news-print purposes, loblolly-pine pulp could no doubt be used as a filler. Tests were made on wood cut in the spring and allowed to remain in the forest until the bark became loosened and on wood cut in the fall and split for fire-wood. The fall-cut wood produced a creamy colored pulp, while the spring-cut wood gave one of a brownish shade. Practically no other difference was noted in the quality. The yield from the fall-cut wood was about 2,500 pounds per hundred cubic feet of rossed wood, while that from the spring-cut wood was 2,400 pounds, the amount in each case being proportional to the weight per cubic foot of the wood.

Through a mistake in shipment a quantity of white pine (*Pinus strobus*) was received at the laboratory. It had not been the intention to test this wood, since its value for lumber eliminates it from consideration as a possible substitute for spruce. Tests were made on it, however, since it was at hand. It can be ground on a fairly sharp stone to yield fibers of good strength and excellent color. The pulp contains a considerable amount of pitch, and, like that from the other pines, is inclined to be soft. The yield was approximately 1,885 pounds per hundred cubic feet of solid rossed wood.

THE SPRUCES.

Engelmann spruce (*Picea engelmanni*) can be ground under the same conditions used for white spruce. The pulp has an excellent color and a long strong fiber. The fact that the wood ground at the laboratory was in a green state undoubtedly made it easier to produce a good grade of pulp. Wood obtained from Colorado in the form of small logs showed no difference in quality from similar material obtained from Montana, though the latter, owing to its greater weight per cubic foot, yielded about 2,250 pounds of pulp (bone dry) per hundred cubic feet of rossed wood against 2,000 pounds for the Colorado material.

Sitka spruce (*Picea sitchensis*) yields a pulp of very good quality, though not equal to that from white spruce. Although the wood can be ground under practically any condition of speed, sharpness of stone, and grinder pressure, the fibers are not as fine and long as those of the white spruce. In color, moreover, Sitka spruce pulp is inclined to be grayish. The wood tested was cut during the latter part of April and contained considerable pitch. It undoubtedly would have run better had it been cut earlier in the year. The yield was 2,100 pounds per hundred cubic feet of solid rossed wood, or about 200 pounds less than that from an equal amount of white spruce.

THE HARDWOODS.

Aspen (*Populus tremuloides*) requires the consumption of a large amount of power to produce pulp which will run satisfactorily on the wet machine. If the pulp stone is too sharp or a less amount of power is used, the pulp will be very short. When mixed with spruce, however, it operates very satisfactorily. Aspen pulp possesses good

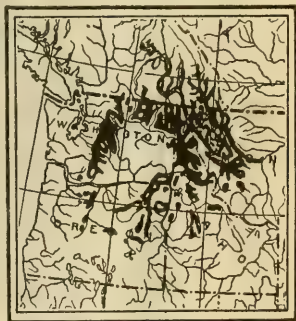


FIG. 33.—Western larch (*Larix occidentalis*).

color, although it is likely to contain black specks of bark unless knots are removed from the wood before it is ground. The yield was approximately 2,200 pounds per hundred cubic feet of solid rossed wood.



FIG. 34.—Lodgepole pine (*Pinus contorta*).

White birch (*Betula papyrifera*) yields a pulp in which the fibers are short, though very fine. It is necessary to use a very dull stone in the grinding process, and even then laps crack along the edges when folded. The pulp, moreover, has a decidedly pinkish tinge, but the ground wood could undoubtedly be used as a filler in the produc-

tion of certain grades of paper. The yield per hundred cubic feet is very high, approximately 2,950 pounds, or 550 pounds more than that from an equal amount of spruce. On the basis of a rough cord, however, this difference would be materially reduced, since white birch logs have a thick bark and are often crooked.

Black gum (*Nyssa sylvatica*) yields a fiber that in many ways resembles that obtained from white birch. It is extremely short, but forms a tougher sheet than coniferous fibers of the same length. Considerable power must be expended to produce laps that can be



FIG. 35.—Western yellow pine (*Pinus ponderosa*).

taken off the wet machine satisfactorily. The pulp is not promising from a news-print standpoint, but could be used as a filler or mixed with pulp of a better grade. In color it is very white, ranking high in this respect among the woods tested. Steaming the wood prior to grinding gives a stronger pulp, but not to the extent observed in the case of birch similarly treated. The yield of pulp from black gum is approximately 2,600 pounds per hundred cubic feet of solid rossed wood.

WOODS STEAMED PREVIOUS TO GRINDING.

In addition to the tests on untreated wood, other tests were made on steamed material. Practically all of the conifers yielded fairly strong, brownish-colored pulps suitable for the production of board and cheap grades of brown wrapping paper. Balsam fir, noble fir, amabilis fir, Alpine fir, and white and Engelmann spruce pulps showed longer fibers and felted somewhat better than those from the other woods. When steamed all of the conifers required the consumption of a relatively large amount of power for the production of satisfactory pulps. This was not the case, however, with aspen and



FIG. 36.—Jack pine (*Pinus divaricata*).

white birch, which produce much stronger pulps when treated before grinding, the product comparing favorably in color and toughness with spruce pulp. The fibers of the aspen and white birch were shorter, it is true, than those of spruce, but the felting qualities of the hardwood pulps are better than those of spruce pulp. Steamed aspen and white birch can be ground with a comparatively small amount of power to produce the kind of pulp just described.

A heavy loss in wood substance was noted in the case of all the species tested except western larch. The fibers of the latter wood seem to become tougher as the result of cooking and do not grind up to a fine powder which passes through the meshes of the cylinder mold.

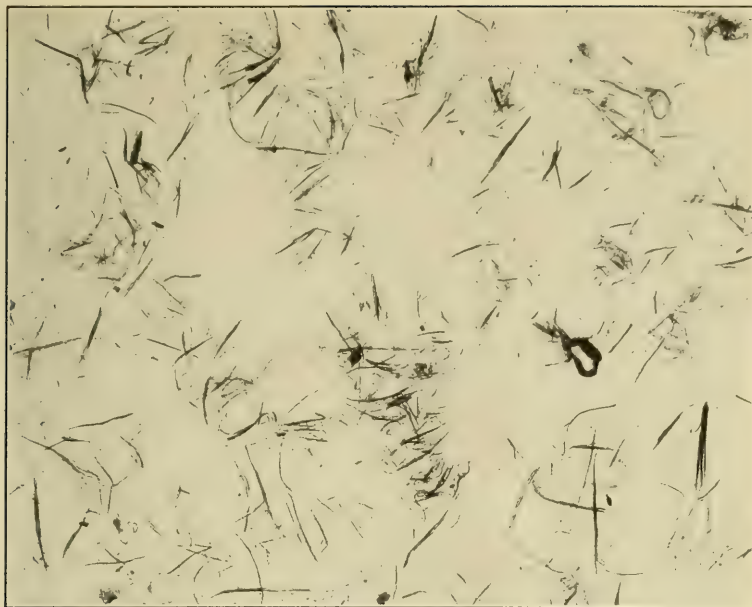


FIG. 1.—UNSTEAMED (RUN No. 2).

F-LAB. 10

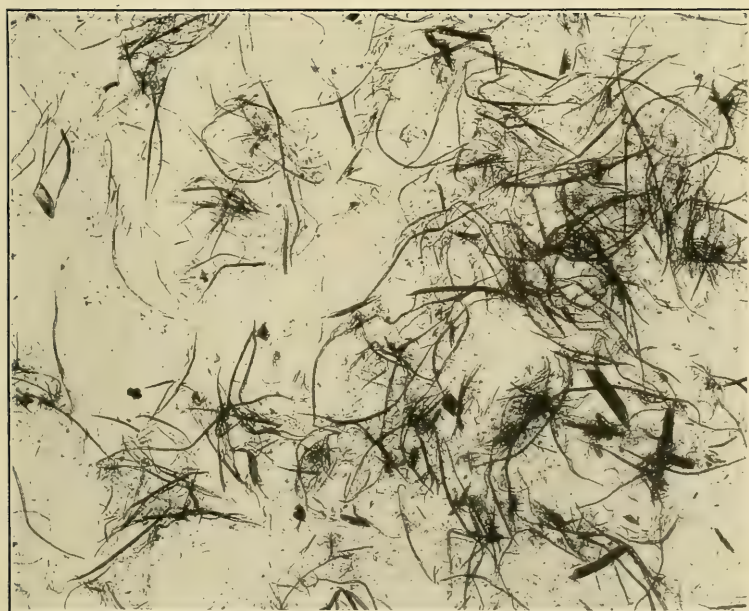


FIG. 2.—STEAMED (RUN No. 3).

F-LAB. 11

WHITE BIRCH MECHANICAL PULP.

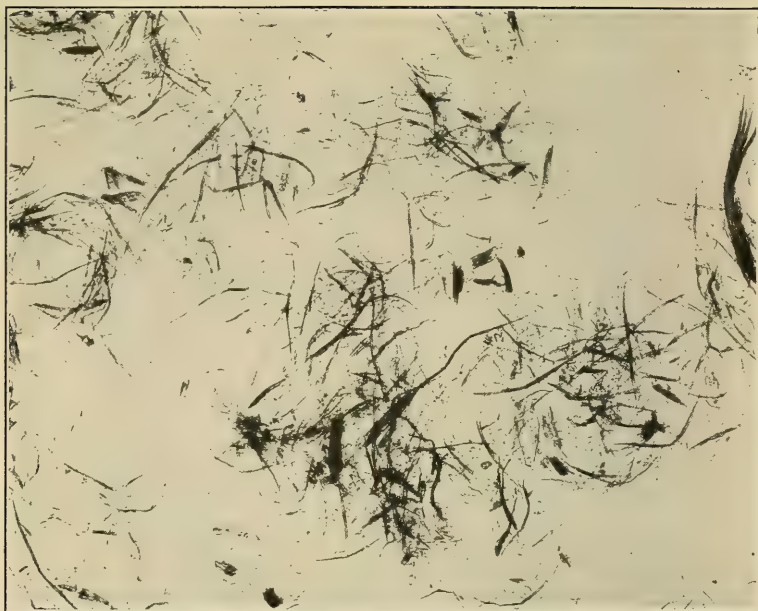


FIG. 1.—STEAMED (RUN No. 5).

F-LAB. 12



FIG. 2.—UNSTEAMED (RUN No. 2).

F-LAB. 13

ASPEN MECHANICAL PULP.



FIG. 1.—UNSTEAMED (RUN No. 56).

F-LAB. 14



FIG. 2.—STEAMED (RUN No. 62).

F-LAB. 15

HEMLOCK MECHANICAL PULP.

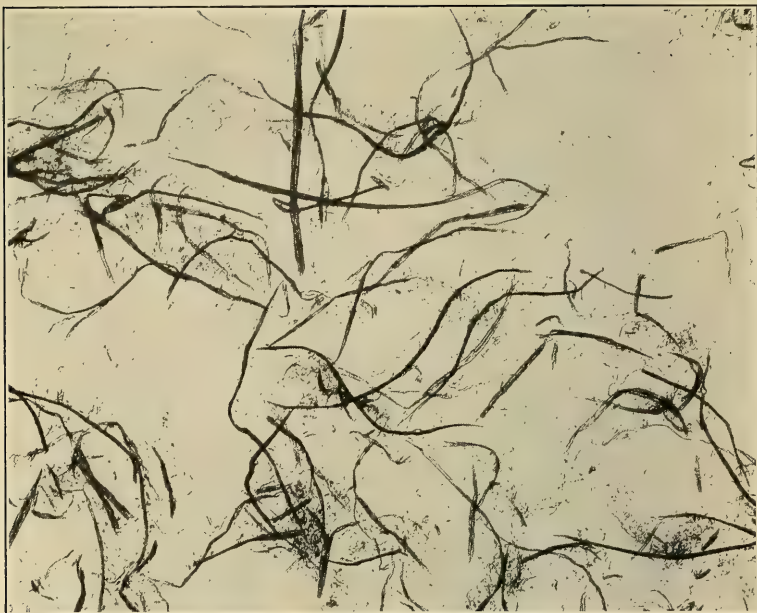


FIG. 1.—STEAMED (RUN No. 30).

F-LAB. 16



FIG. 2.—UNSTEAMED (RUN No. 27).

F-LAB. 17

JACK PINE MECHANICAL PULP.

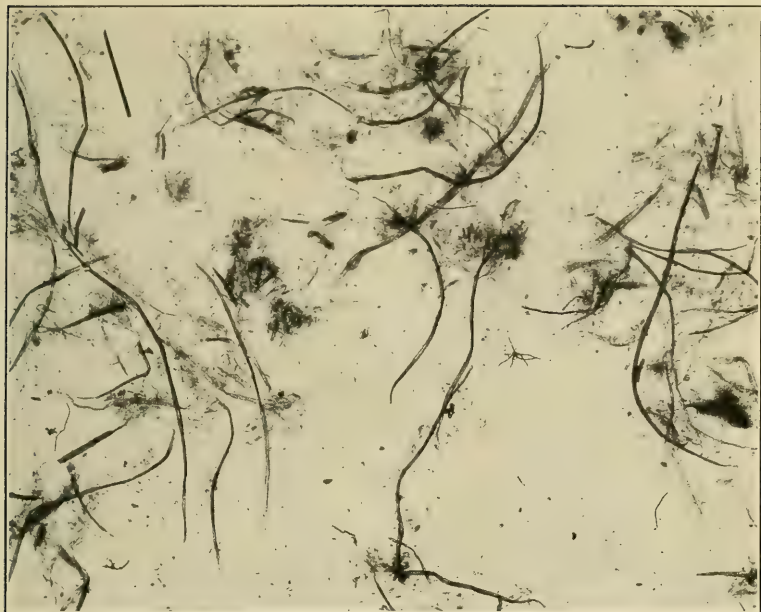


FIG. 1.—STEAMED (RUN No. 25).

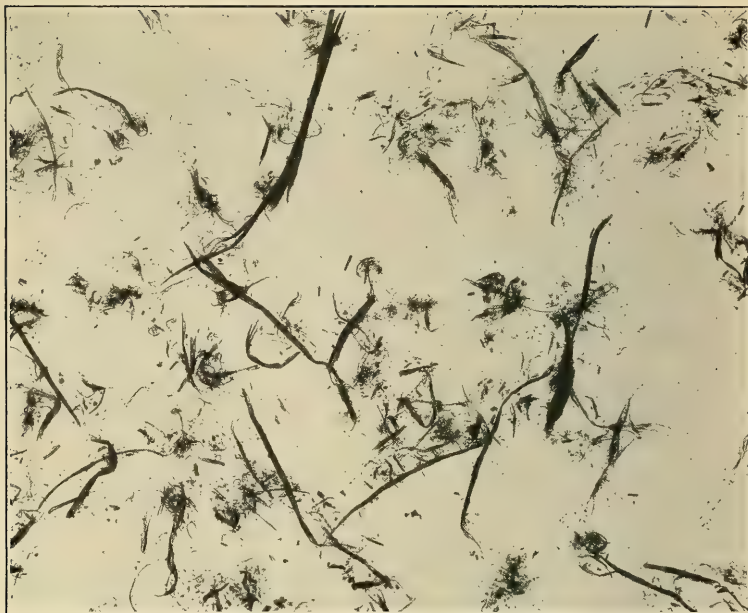
F-LAB. 18



FIG. 2.—UNSTEAMED (RUN No. 26).

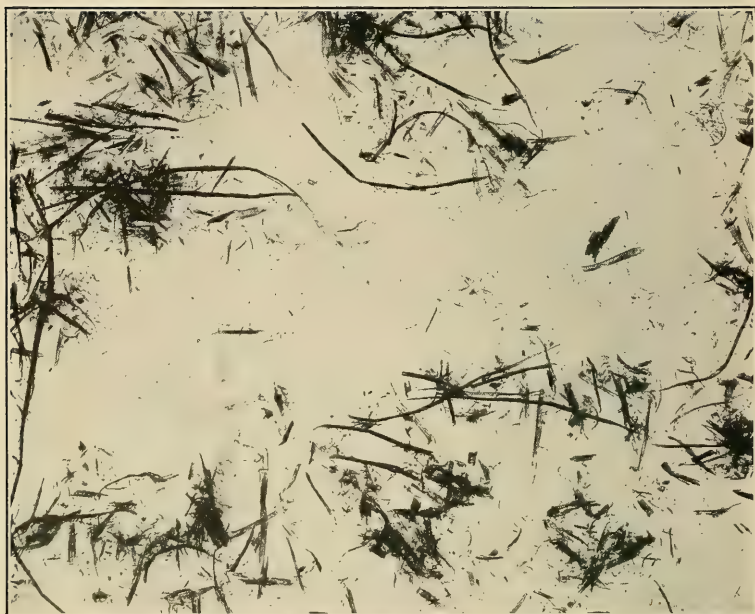
F-LAB. 19

TAMARACK MECHANICAL PULP.



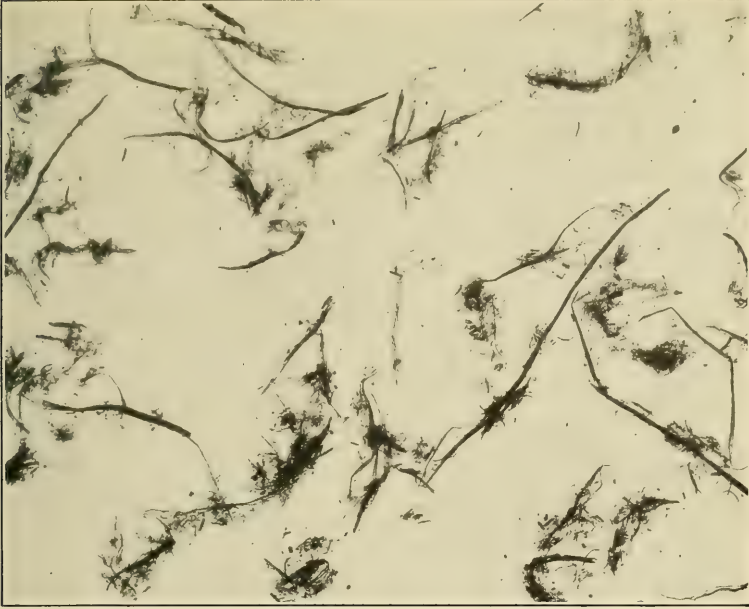
F-LAB. 20

FIG. 1.—RED FIR MECHANICAL PULP UNSTEAMED (RUN No. 4).



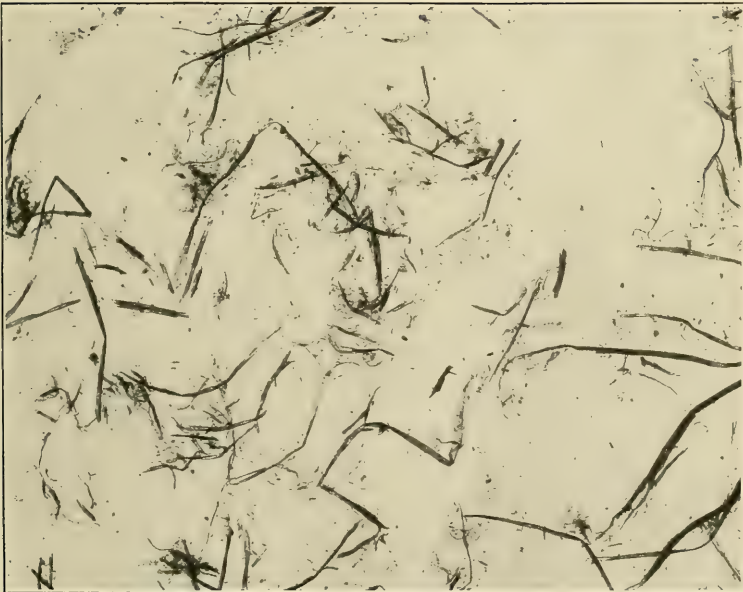
F-LAB. 21

FIG. 2.—WESTERN LARCH MECHANICAL PULP UNSTEAMED (RUN No. 2).



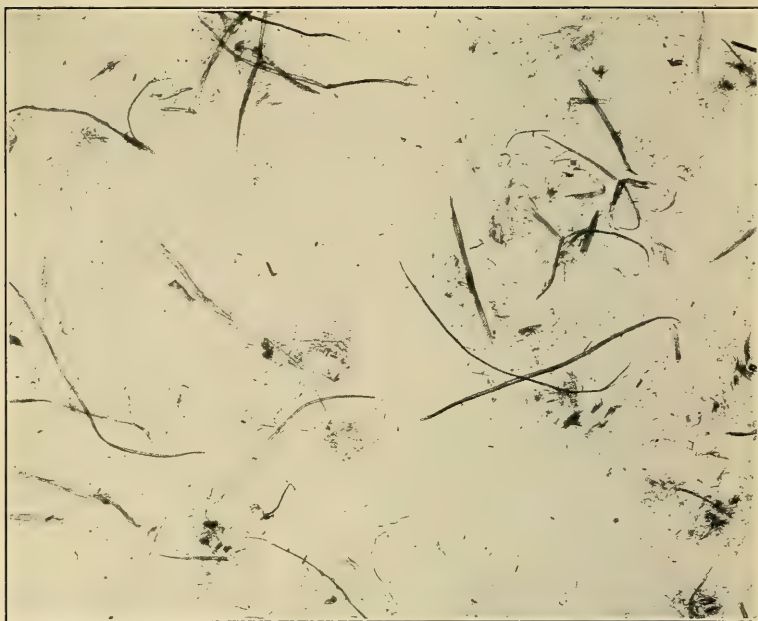
F-LAB. 22

FIG. 1.—WESTERN HEMLOCK MECHANICAL PULP UNSTEAMED (RUN No. 1).



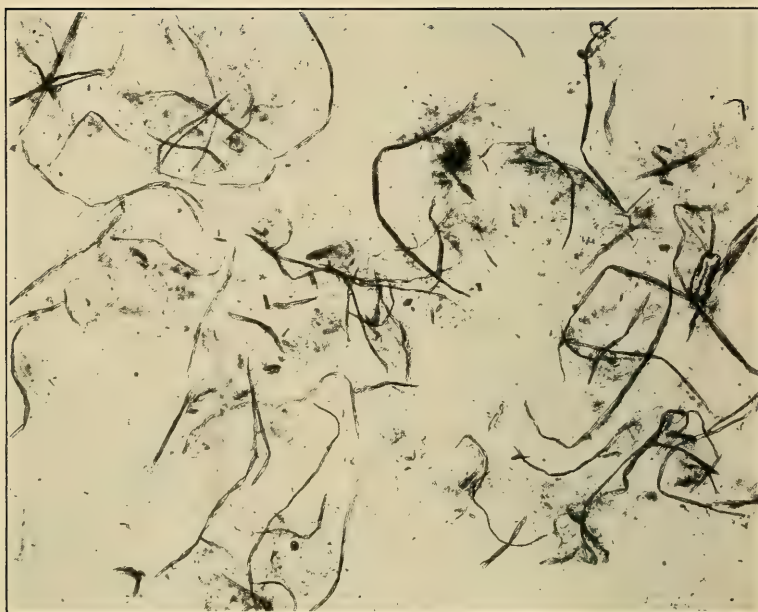
F-LAB. 23

FIG. 2.—LODGEPOLE PINE (CALIFORNIA) MECHANICAL PULP UNSTEAMED (RUN No. 2).



F-LAB. 24

FIG. 1.—WESTERN LARCH MECHANICAL PULP STEAMED (RUN No. 1).



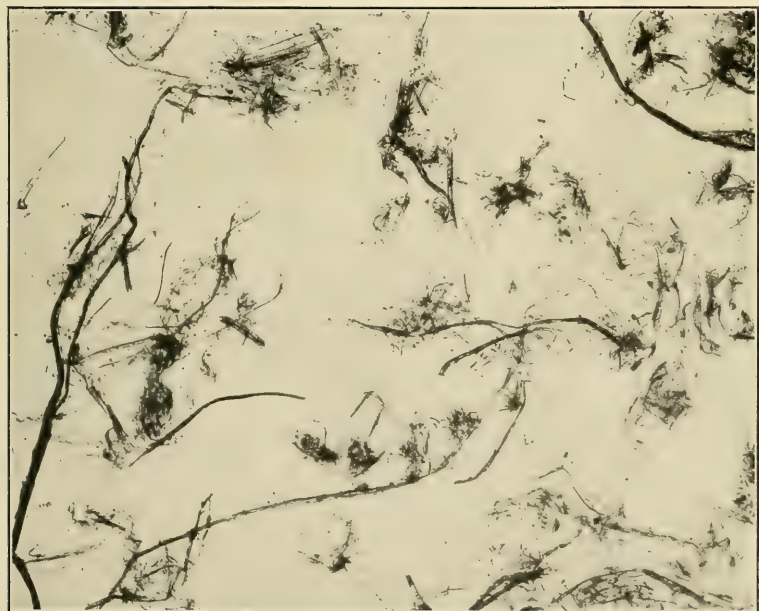
F-LAB. 25

FIG. 2.—LODGEPOLE PINE (CALIFORNIA) MECHANICAL PULP STEAMED (RUN No. 1).



F-LAB. 26

FIG. 1.—BALSAM FIR MECHANICAL PULP UNSTEAMED (RUN NO. 14).



F-LAB. 27

FIG. 2.—NOBLE FIR MECHANICAL PULP UNSTEAMED (RUN NO. 2).

MICROSCOPIC COMPARISON OF GROUND-WOOD FIBERS.

Plates IV to XII are photomicrographs of the ground-wood fibers obtained from the various species tested. It is not possible, of course, to gauge accurately from such photographs the pulp-making qualities of the fibers. Length of fiber does not necessarily mean strength, for a stronger pulp can be obtained from fibers which, though quite short, will felt well. Steamed white birch pulp, for example, will test as high in strength as longer-fibered material from the pines, larches, and hemlocks. However, the photographs make it possible to compare the characteristics of the fibers of one kind of wood with those of another kind, especially since the lodgepole pine,



FIG. 37.—Loblolly pine (*Pinus taeda*).

western hemlock, western larch, red fir, balsam, white birch, jack pine, hemlock, and tamarack were ground under the same conditions of pressure, speed, surface of stone, etc. For some of these species photographs of both cooked and uncooked fibers are shown. The cooked-wood specimens were not treated in the same manner, nor were they ground under like conditions.

In the case of birch (Pl. IV) it will be seen that the uncooked pulp is very short and contains much wood flour, while the cooked fibers are fairly long and very fine. When run into paper without the addition of sulphite the steamed pulp showed a strength under test of 0.51 point per pound and 5.8 points per thousandth inch of thickness.

The aspen fibers (shown in Pl. V) appear to be even shorter than those of the birch. The steamed pulp when run into a 63-pound sheet gave a Mullen test of 0.51 point per pound and 6.2 points per thousandth inch of thickness.

Between the cooked and uncooked hemlock fibers (shown in Pl. VI) there is more contrast in respect to length than in the case of birch and poplar. The cooked hemlock when run into a 55-pound sheet without sulphite gave a Mullen test of 0.51 point per pound and 6 points per thousandth inch of thickness.

Both the steamed and unsteamed jack pine (shown in Pl. VII) are remarkably free from wood flour and short fiber. The steamed-



FIG. 38.—White pine (*Pinus strobus*).

wood sample, when run into a 43-pound sheet without sulphite, gave a Mullen test of 0.47 point per pound and 4.5 points per thousandth inch of thickness.

In Plate VIII, which shows steamed and unsteamed tamarack fibers, the much greater length of the former is apparent.

Plates IV, VI to X, and XII, figure 1, show the fibers from a number of different woods ground in the natural state under the same conditions. With the exception of western larch, the fibers are of very good quality and compare well with those of spruce. So far as length and fineness go, the fibers shown in Plates VII, X, and XII are fully equal to spruce.

EXPERIMENTAL MANUFACTURE OF PAPER.

A limited amount of paper (waterleaf) was made experimentally at the Madison laboratory from the various pulps and tested for strength and color. In every case the conditions of manufacture were identical, and no coloring matter was added to any of the pulps in the beater. The paper machine used was too small to permit of

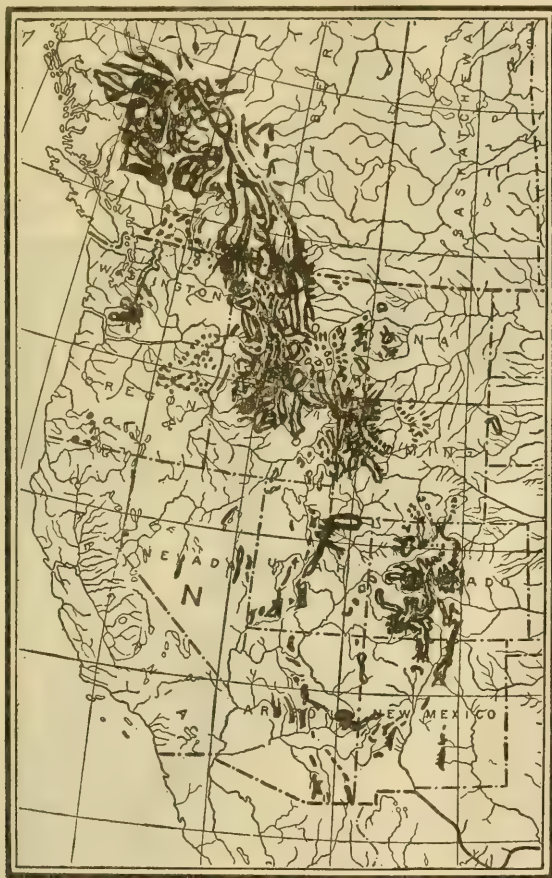


FIG. 39.—Engelmann spruce (*Picea engelmanni*).

reliable data being obtained upon such points as operation of the pulp on the machine, calendering, and the like.

In the matter of color the various wood fibers (unsteamed) may be arranged in the order given below, the basis being the number of parts of black which each sample contained, that with the smallest number ranking first. It should be remembered that the arrangement is made as the result of tests on many different samples of paper from the same wood, rather than on the particular samples

which accompany this bulletin, and also that the different woods were in various stages of seasoning when ground into pulp, a fact which might materially influence their relative color rating:

- | | |
|--------------------------------|--|
| 1. Alpine fir. | 14. Jack pine. |
| 2. White spruce. | 15. White fir (old and young trees mixed). |
| 3. Engelmann spruce. | 16. Noble fir. |
| 4. Black gum. | 17. Loblolly pine (spring cut). |
| 5. Lowland fir. | 18. Aspen. |
| 6. Montana lodgepole pine. | 19. White birch. |
| 7. Loblolly pine (fall cut). | 20. Sitka spruce. |
| 8. White pine. | 21. Eastern hemlock. |
| 9. Balsam fir. | 22. Red fir. |
| 10. White fir (young wood). | 23. Tamarack. |
| 11. Western yellow pine. | 24. Western hemlock. |
| 12. California lodgepole pine. | 25. Larch. |
| 13. Amabilis fir. | |



FIG. 40.—Sitka spruce (*Picea sitchensis*).

White, Alpine, amabilis, and balsam fir are light in color, comparing very favorably in this respect with white spruce. Red fir and noble

fir, however, have a pinkish tinge, as has eastern hemlock and white birch. Western hemlock is grayish. Lodgepole pine has a good color, but western yellow pine is a yellowish white, and jack pine and loblolly have a brownish tinge. Both western larch and eastern larch



FIG. 41.—White spruce (*Picea canadensis*).

(tamarack) are of poor color for news-print purposes, the former being very brown and the latter dark gray. Aspen and black gum have a good color. Sitka spruce is gray, but Engelmann spruce is fully as bright as white spruce.

It is very difficult to obtain reliable data on the relative strength of pulps from different woods, owing to the fact that it is almost impossible to produce them under identical conditions of grinding, especially as regards power consumption per ton, a factor which largely influences their strength. The result of strength tests made at the laboratory on the experimental pulps seems to indicate, however, that but one of them surpasses white spruce pulp. This refers,



FIG. 42.—Aspen (*Populus tremuloides*).

of course, to the uncooked pulps. Tests made on the steamed pulps indicate that those from the hardwoods produced with a smaller consumption of power surpass white spruce in bursting strength. If the results of tests on the breaking length in meters per horsepower per ton and those of the horsepower per ton per point per pound are averaged for power consumptions of from 80 to 100 horsepower, the experimental woods can be arranged in the following order as regards their strength, the strongest coming first:

- | | |
|-----------------------------|--------------------------------|
| 1. Noble fir. | 13. California lodgepole pine. |
| 2. White spruce. | 14. White pine. |
| 3. Amabilis fir. | 15. Western yellow pine. |
| 4. Engelmann spruce. | 16. Tamarack. |
| 5. Western hemlock. | 17. Jack pine. |
| 6. Sitka spruce. | 18. Loblolly pine. |
| 7. Balsam fir. | 19. Hemlock. |
| 8. Lowland fir. | 20. Larch. |
| 9. Red fir. | 21. Aspen. |
| 10. Montana lodgepole pine. | 22. Black gum. |
| 11. White fir. | 23. Birch. |
| 12. Alpine fir. | |

COMMERCIAL MANUFACTURE OF PAPER.

To secure reliable data on the operation of the pulps on the paper machine approximately 5,000 pounds of bone-dry pulp were manufactured from each kind of wood. At the start 5 tons of pulp were made, but it was found later that the smaller amount would be sufficient for the purpose of the test. The papers were made at the mills of the Rhinelander Paper Co., Rhinelander, Wis., and the Nekoosa-Edwards Paper Co., Port Edwards, Wis. The woods and mixtures of woods used were as follows:

- | | |
|---|--|
| Jack pine, green. | 7. California lodgepole pine. |
| Jack pine, seasoned. | 8. Red fir. |
| Hemlock. | 9. One-half spruce and one-half hemlock. |
| One-third spruce, two-thirds hemlock. | 10. One-half balsam fir and one-half spruce. |
| One-third spruce, one-third hemlock, and one-third jack pine. | 11. Tamarack. |
| Two-thirds hemlock, one-third jack pine. | 12. One-half tamarack and one-half spruce. |
| 1. Spruce. | 13. Noble fir. |
| 2. Western hemlock. | 14. Alpine fir. |
| 3. Sitka spruce. | 15. White spruce. |
| 4. Montana lodgepole pine. | 16. Engelmann spruce (Colorado). |
| 5. Western yellow pine. | 17. Amabilis fir. |
| 6. Balsam fir. | |

As the former group of tests has been previously reported upon (Forest Service Bulletin, "Experiments with Jack Pine and Hemlock for Mechanical Pulp"), only the last 17 papers manufactured at the Nekoosa-Edwards Paper Co. will be considered.

Table 57 gives the results of the commercial runs. Samples of the printed and unprinted sheets accompany this bulletin.

For the first 12 runs the same furnish of ground wood and sulphite to the beater was used in each case, the pulp consisting of quick-cook hemlock sulphite 25 per cent and experimental ground wood 75 per cent. In the last five tests the pulp was made up of 20 per cent of



FIG. 43.—White birch (*Betula papyrifera*).

quick-cook sulphite and 80 per cent of ground wood. The complete list of material furnished the beaters is given in Table 2.

The quantities of the different colors added varied with the color of the pulp. In every case attempt was made to duplicate the standard news color used by the company manufacturing the paper. It is very probable that if the sheets had been left uncolored, or had



FIG. 44.—Black gum (*Nyssa sylvatica*).

been colored a cream white, they would have presented a better appearance than they did.

Of the first series of 12 tests, those on white spruce, balsam fir, and Sitka spruce were run on a Fourdrinier paper machine trimming 109 inches wide and having a jacketed upper couch roll. On account of the slowness of the stock and insufficient suction the operation of the pulps in these three tests was somewhat unsatisfactory. There was sticking of the pulp to the couch and difficulty in securing good formation.

TABLE 2.—*Furnish to beater on basis of 1,000 pounds of paper. Commercial tests on experimental pulps.*

Stock No.	Kind of ground wood.	Weight.	Sulphite.	Size.	Alum.	Soluble blue HA.	Rhodamine B extra.
		<i>Pounds.</i>	<i>Pounds.</i>	<i>Pounds.</i>	<i>Pounds.</i>	<i>Ounces.</i>	<i>Ounces.</i>
1	Spruce.....	750	250	3.33	6.67	3.2	0.167
2	Western hemlock.....	750	250	3.33	6.67	4.27	.10
3	Sitka spruce.....	750	250	3.33	6.67	3.37	.167
4	Lodgepole pine (Montana).....	750	250	3.33	6.67	3.33	.20
5	Western yellow pine.....	750	250	3.33	6.67	4.27	.267
6	Balsam fir.....	750	250	3.33	6.67	2.53	.167
7	Lodgepole pine (California).....	750	250	3.33	6.67	3.2	.167
8	Red fir.....	750	250	3.33	6.67	3.73	.133
9	Hemlock and spruce.....	1750	250	3.33	6.67	3.73	.20
10	Balsam and spruce.....	1750	250	3.33	6.67	2.6	.167
11	Tamarack.....	750	250	3.33	6.67	5.33	.667
12	Tamarack and spruce.....	1750	250	3.33	6.67	4.00	.4
13	Noble fir.....	800	200	3.33	10.0	5.4	.40
14	Alpine fir.....	800	200	3.33	10.0	4.4	.40
15	White fir.....	800	200	3.33	10.0	6.8	.30
16	Engelmann spruce (Colorado).....	800	200	3.33	10.0	4.8	.375
17	Amabilis fir.....	800	200	3.33	10.0	5.0	.400

1375 pounds each.

The remainder of the 12 tests were run on a Fourdrinier machine trimming 100 inches and provided with a suction couch roll. The operation of pulp on this machine was much more satisfactory than on the other, although slowness of the stock made it impossible to use the dandy and a good formation could not be secured. Both of the paper machines ran at a speed of 460 feet per minute, and the screen plates were cut with slots 0.011 inch wide. In calendering the paper, 9 nips of a 12-roll calender stack were used.

So far as appearance and strength went, all the sheets manufactured at this time were considered very creditable. The No. 9 paper, containing $37\frac{1}{2}$ per cent of hemlock ground wood, $37\frac{1}{2}$ per cent of spruce ground wood, and 25 per cent of quick-cook hemlock sulphite, had a very high strength and took an excellent finish, though the color was slightly off. Both of the balsam sheets—No. 6 and No. 10—were very good both in strength and color. The western yellow-pine sheet ran very foamy and showed a number of scum spots, due largely to the pitch. Sheets of better formation undoubtedly could have been made if the pulp had been ground in a way to make it somewhat more “free.” The Jordan machine was not used except to brush out the sulphite.

For the last 5 of the 17 commercial runs it was necessary to return to the first paper machine. In this series the paper was run at a speed of 450 feet per minute and passed through 11 nips of a 12-roll calender stack. All of the stocks were somewhat slow, but not so slow as were those of the previous series. The formation of the sheets, however, left much to be desired. Engelmann spruce (stock 16) and Alpine fir (stock 14) operated very satisfactorily with the dandy in use, but the stock from amabilis fir (stock 17) was very slow and sticky, and the dandy was removed for noble fir (stock 13) and white fir (stock

15). In this series the jordan in every case brushed as close as, or closer than, when the regular mill stock was being used.

The ground wood from Alpine fir and Engelmann spruce gave the best results from the standpoint of operation on the paper machine. All of the sheets in this series exhibited very good strength, while the color of those from Alpine fir, amabilis fir, and Engelmann spruce compared favorably with that of the spruce standard. So far as the paper-making qualities of the pulps are concerned, the 17 tests demonstrate that all of the woods used are satisfactory for news-print paper. It was suggested by the men operating the paper machines that even more satisfactory results could have been secured had a lighter sheet been run, such as is used for catalogues. Table 58 summarizes the results of strength and color tests on the papers manufactured from the commercial pulp samples. If the results of the single trial to obtain a good color for each experimental sheet are compared with the color ratings given in Table 3 for a few actual trade news-print sheets, it will be seen that the latter vary almost as widely in color as the experimental papers.

TABLE 3.—*Color ratings of commercial news-print sheets.*

	Red.	Green.	Blue.	Black.		Red.	Green.	Blue.	Black.
A.....	61	59	54	126	K.....	66	61	59	114
B.....	61	67	50	132	L.....	68	60	58	114
C.....	66	62	59	112	M.....	71	61	59	109
D.....	61	59	54	126	N.....	58	56	56	130
E.....	69	65	60	106	O.....	65	58	57	120
F.....	70	66	54	110	P.....	56	55	55	134
G.....	61	59	54	126	Q.....	61	59	58	122
H.....	69	61	59	111	R.....	69	57	57	117
I.....	60	54	54	132	S.....	64	54	54	120
J.....	65	59	59	116					

TESTS ON NEWSPAPER PRESSES.

The final test of news-print paper is, of course, its behavior on the presses and the way it takes ink. Defects which are not apparent when the material is run over the machine become very evident when the paper is run through a high-speed press. Under such conditions, holes, calender cuts, and the like cause the paper to break.

The first 12 experimental papers were tested on the presses of the St. Louis Republic, St. Louis, Mo. They were run on two duplicate machines of the Hoe sextuple rotary type. Some of the rolls of experimental paper were 67 inches wide, others were 50½ inches, and still others 33½ inches wide. One entire city edition and a portion of another were printed on the experimental papers.

On one press the papers were run at the rate of 369 copies per minute, and on the other at the rate of 372 per minute, or 22,150 and 22,300 copies per hour, respectively. This corresponds to a speed of paper through the press of approximately 760 feet per minute.

Allowing for breaks and other interruptions, the actual number of papers printed per hour under ordinary conditions ranges from 10,000 to 19,000, depending on the quality of the paper used. In the case of the experimental papers none of the ordinary conditions of operation in the pressroom were changed in any particular. A single speed was maintained throughout the tests and the only adjustments made were those necessary to secure a good-looking sheet, such as changing the supply of ink to various portions of the type and adjusting the tension on the paper. Under ordinary conditions of operation in the pressroom of the St. Louis Republic there is one break to each ton (2,000 pounds) of paper run through the press. With the paper ordinarily used, 1,000 eight-page papers weigh 113 pounds. This corresponds to a sheet weighing approximately 31 pounds per ream of 500 sheets, 24 by 36 inches in size.

From Table 4, which gives the results of the printing tests, it will be seen that in some of the rolls, particularly those of white and Sitka spruce, there were a great many breaks. Almost all of these were due, however, to calender cuts on the edges of the sheets, scum spots, defective mill pasters, and poor winding. In the main, they were the result of inability to secure the best operating conditions on the paper machine before the supply of experimental pulp became exhausted. Difficulty with the spruces led us to believe that with proper operation on the machine practically all the trouble could have been eliminated.

TABLE 4.—*Printing-press data—experimental papers.*

ST. LOUIS REPUBLIC, APR. 29-30, 1913—67-INCH ROLLS.

Stock No.	Weight at mill.	Tare. ¹	Loss in transit.	Weight of wrapper.	Weight of paper at press.	Number of 8-page papers produced. ²	Weight per 1,000 8-page papers.	Weight per 500 24 by 36 inch sheets.	Number of breaks.	Remarks.
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.		Lbs.	Lbs.		
6	1,015	50	12	13.5	939.5	8,950	104.97	28.64	.....	Run good.
10	1,478	44	17	20.0	1,397	13,020	107.29	29.24	5	Breaks due to bad winding.
4	1,494	60	23	25.0	1,386	12,660	109.47	29.85	8	Breaks due to calender cut (and holes).
2	1,567	53	16	18.0	1,480	13,710	107.95	29.41	.....	Run good.
8	1,513	44	.....	20.0	1,449	11,890	121.86	33.22	.....	Do.
7	1,516	43	16	18.0	1,439	12,030	119.61	32.61	.....	Do.
5	1,425	56	21	22.0	1,326	11,850	111.89	30.49	6	Breaks due to calender cuts.
11	1,321	41	82	19.0	1,179	10,220	115.36	31.44	3	Breaks due to calender cuts (and holes).
12	1,473	44	11	19.5	1,398.5	11,370	123.00	33.56	1	Unknown (cuts on end of roll).

ST. LOUIS REPUBLIC, APR. 29-30, 1913—50½-INCH ROLLS.

1	1,046	44	10	12.0	980	11,600	112.64	30.71	8	Breaks due to bad winding.
1	1,191	33	.....	6.0	1,152	13,580	113.10	30.84	3	2 breaks from scum spots, 1 from mill paster.
3	927	32	25	7.0	863	9,920	115.99	31.62	14	11 due to calender cuts, 3 to bad winding.
3	873	45	6	7.0	815	9,400	115.60	31.53	3	Due to calender cut and mill paster, cuts, and holes.
9	1,134	31	.....	15.0	1,088	12,270	118.22	32.22	4	Do.
9	1,027	32	.....	9.0	986	11,020	119.29	32.52	.....	Run good.

TABLE 4—*Printing-press data—experimental papers—Continued.*

ST. LOUIS REPUBLIC, APR. 29-30, 1913—33½-INCH ROLLS.

Stock No.	Weight at mill.	Tare. ¹	Less in transit.	Weight of wrapper.	Weight of paper at press.	Number of 8-page papers produced.	Weight per 1,000 8-page papers.	Weight per 500 24 by 36 inch sheets.	Number of breaks.	Remarks.
6	Lbs. 464	Lbs. 22	Lbs. 9	Lbs. 12.0	Lbs. 421	8,590	Lbs. 98.02	Lbs. 26.74	1	Run good; mill pasteur.
NEW YORK HERALD, FEB. 14, 1914—66-INCH ROLLS.										
13	1,386	145	72	19.0	1,241	³ 12,170	101.96	30.0	.....	Run fair; breaks due to bad winding.
14	1,361	97	44	19.0	1,245	³ 11,422	109.00	31.5	.....	Run good.
15	1,346	340	280	19.0	987	⁴ 9,055	109.00	31.5	.....	Do.
16	1,224	103	50	19.0	1,102	⁸ 9,325	118.18	34.0	.....	Run fair.
17	1,181	80	40	19.0	1,082	⁴ 9,155	118.18	34.0	.....	Run good.

¹ Figures for New York Herald run include waste and core.³ 150 spoils.² No data on number of spoils taken at St. Louis.⁴ 100 spoils.

So far as inking qualities and finish were concerned, the experimental papers were entirely satisfactory. Many of the sheets, however, had a muddy appearance, particularly when placed beside the light-colored all-spruce sheet. It was the opinion of the pressmen that, notwithstanding this, most of the sheets were very fair. Those which seemed most promising were the balsam sheet (stock 6,) which ran very satisfactorily, though light in weight, and in color compared favorably with the all-spruce sheet, and stock 9, containing 37½ per cent of hemlock ground wood and 37½ per cent of spruce ground wood, which compared very favorably in color and printing qualities with ordinary news-print paper. Both of the lodgepole sheets and the red-fir sheet also had a good color. The tamarack sheets (stocks 11 and 12) ran well, but were dark. The following is an extract from the St. Louis Republic regarding the trial runs of the experimental papers.

The paper was used to print a part of the issue of the Republic on both Tuesday, April 29, and Wednesday, April 30, these trial runs being the first and only efforts so far made to use the experimental paper in a commercial way. The Republic volunteered to cooperate with the Government laboratory, and is gratified that it can report the paper used was of a quality to justify hopeful anticipation that substitute woods can be used which will serve to hold a good part of the paper-making industry on American soil. * * *

RESULTS ENCOURAGING.

As already remarked, the experimental runs developed results that were quite distinctly encouraging. These, however, can not be appraised with any measure of exactness for several reasons. First of these was the fact that there was not enough of any one particular make of paper to enable the pressmen in charge of the Republic's presses to acquire the familiarity that tends to good results. Sixteen rolls were sent for trial, and in only three instances were there as many as two rolls of the same par-

ticular composition. To make this handicap greater, it was necessary to constantly run two rolls of wholly different component materials at the same time, so that the press data was inevitably mixed and breaks in the running couldn't be traced with the same satisfactory certainty that would have followed if only one kind of a paper at a time had been running on a press. The weight of the paper was also extremely variable, and tension set for a roll running heavy would, of course, have to be set differently for another roll running much lighter in weight. Despite these handicaps the demonstration was notably satisfactory in respect to running strength in more than one instance.

The conventional standard of the paper mills, in the matter of weight, is 32 pounds for 500 sheets measuring 24 by 36 in size, yet one roll of the experimental paper, which weighed only 26.74 pounds, had but one break. This particular paper was made from balsam fir and was of unmistakably good quality apart from its quite surprising strength. Another roll of the same composition ran without a single break, and the trials apparently gave conclusive proof that balsam fir is good paper-making material. The red-fir paper also showed good results, but the weight being 33.22 pounds, the demonstration was not quite so conclusive.

SUCCESS WITH NEW MATERIALS.

Taking all factors into consideration, strength, color, and finish, the paper made from balsam and spruce ground wood in equal proportions, roll No. 10, stock number, was the most completely satisfactory. This paper weighed only 29.24 pounds, and the five breaks that occurred in running it were attributed entirely to improper winding. The paper made from white spruce ground wood showed unexpected lack of strength, speaking relatively, but, as might be assumed, was comparatively good in color. The matter of color is the point on which the most serious criticism can be made, but there is good reason for believing that this fault can be remedied. Consumers of paper always count on more or less difficulty at the start in getting the color established at a satisfactory standard, so this experimental paper can not be fairly condemned on that ground.

But one kind of chemical pulp was used in the manufacture of these rolls, as the list already given indicates. It was hemlock sulphite in every instance. One roll, stock No. 2, was made entirely from hemlock, both ground wood and chemical pulp. This paper was somewhat dark, but it showed good strength. The press report shows five breaks, but they are attributed to winding rather than to the weakness of the paper notwithstanding it averaged only 29.24 pounds. Paper manufacturers have used hemlock pulp for years to more or less extent, but usually mixed with spruce, and it has never been ranked in the same class as spruce in the matter of quality. Ground wood made from hemlock has a tendency to develop unfelted fiber that stands up like whiskers on the surface of the paper, but the paper made from the Wausau laboratory pulp was notably free from this particular bad quality.

The last five experimental paper stocks were tested on the presses of the New York Herald, New York City. A 66-inch roll of each paper, weighing approximately 1,200 pounds, was used. This amount was sufficient for only a part of one city edition. It was impossible, moreover, to run each stock over the same press, and the five rolls were divided among three Goss sextuple presses. In all cases the sheet was printed at the rate of 400 eight-page papers per minute, or 24,000 per hour, equal to a speed through the press of 760 linear feet per minute. As in the case of the tests at St. Louis, the pressmen did not depart from their ordinary practice except for slight adjustment of tension upon the sheet and impression

of the type required by the particular stock being printed. During shipment to New York the roll made from white fir (stock 15) and that from amabilis fir (stock 17) were considerably battered and torn at the edges. This caused the rolls to run unevenly at the start, though after a short time no trouble was experienced.

The paper from Alpine fir (stock 14) gave a good, clean, white sheet, had a good surface, took ink well, and from the printer's standpoint was considered the best sheet of the series. The amabilis fir paper (stock 17), although not as well formed, had a good surface, brought out the cuts fairly well, and was ranked second in the series. In general, the papers fed smoothly and the few irregularities met with were due to defects which could be easily prevented after a little experience in manufacture.

Following is an extract from the New York Herald in regard to the tests:

WORKS WELL ON PRESSES.

When the paper was all run off the foreman said he had had no more difficulty with the experimental Government paper than with any other that ever had been used on the presses. It fed smoothly, and while a slight imperfection appeared here and there, this was attributed to the mechanical irregularities and not to a fault of the pulp stock. The amabilis fir and the Alpine fir were credited with being the best, having a better finish, better surface, better color, and with a much better formation. * * *

The experimental runs developed results that showed that the Government paper was being printed under a handicap. In the first place, there was not enough of any one particular sample of the paper to enable the pressmen to acquire the familiarity that tends to the most perfect results.

With all the paper different in texture, thickness, weight, and formation, it was necessary to run rolls of differing texture together, so that the press data naturally were constantly mixed and the few breaks in the running could not be traced with the same satisfactory certainty that is the case when one kind of paper is feeding through all the parts of the press. The weight of the paper was also variable, compared one roll with another, and the tension set for a roll running heavy would, of course, have to be set differently for another roll running much lighter in weight.

DEMONSTRATION SATISFACTORY.

Another handicap under which the Government experts worked lay in the fact that they had made up such a small quantity of the paper that they naturally did not have as fine a quality as if they had been able to experiment with a dozen rolls before they finally adjusted their machines to the ultimate product. Moreover, in its shipment it had been damaged, so that it rolled unevenly. Despite these handicaps the demonstration was notably satisfactory.

The general impression of the press experts was that the amabilis fir and the Alpine fir had given the best results in the press. These rolls had a blue-white surface and general softness that made it almost impossible to distinguish them from spruce papers.

To obtain the opinions of paper producers and users, samples of the experimental sheets were submitted to a number of manufacturers and publishers. Their comments tend to show that different sheets are favored by different individuals, a fact which

would seem to indicate that almost every sheet is satisfactory to some critic. Some of the comments are as follows:

Some of the papers, especially Nos. 3 and 6, have beautiful color, but none of the samples are any darker than paper I have seen printed commercially, made from spruce ground wood and hemlock sulphite pulp. * * *

Personally I like the appearance of sheets Nos. 6, 9, and 10. Of these, I think sheet No. 9 shows up very well. I can not see why any one of these sheets could not be used for printing newspapers.

I find considerable variation in color when the samples are placed next to each other, but I do not think that the variation is so great that the reader's attention will be called to the color of the paper in any instance. In fact, I have seen many newspapers printed on paper made entirely from spruce wood which did not look nearly so well as the poorest of the samples submitted by you.

All of these samples on the last run seemed to show up very well indeed, and any one of them ought to serve for newspaper purposes.

PROBLEMS IN CONNECTION WITH THE EXPERIMENTAL WOODS.

Some of the woods tested are resinous, which makes them unsuitable for the manufacture of paper on a high-speed machine. There should be some inexpensive way of treating the resinous woods which would not darken them. It is possible that such treatment would have to be given in the beater. At the same time tests should be made on resinous woods at different times of the year, since it is likely that the time of cutting has a material influence on the operation of the pulp on the paper machine.

The color of many of the woods could probably be bettered by a suitable bleaching treatment while the pulp was being manufactured into laps or while the latter were being stored. Experiments might also be made to ascertain whether the sheets which are only slightly off color could not be brought up to the standard of white required for news-print purposes by the addition of dyes.

A problem not directly connected with pulp and paper production, but of importance to it, is that brought about by the decay of the wood when piled at the mill and of the pulp during storage. Some of the experimental woods decay rapidly and are subject to attacks of insects and fungi. Some reasonably cheap method of insuring these woods against decay and insects will have to be found if they are to be used in any quantity.

METHODS OF INCREASING THE EFFICIENCY OF GRINDING.

There are in the United States approximately 1,500 wood-pulp grinders of different sizes, each of which utilizes on the average 350 horsepower continuously. The amount of power applied to grinders has been increasing steadily from year to year. Where in the beginning of the mechanical pulp industry 125 horsepower was used on the grinder, in many cases now 600 to 750 horsepower is employed, and in the case of the automatic magazine grinder from 1,000 to 1,200 horsepower is utilized. Of the total number of grinders in the United States upon which information is available 36 per cent

are driven by turbines and motors of less than 300 horsepower capacity and 8 per cent of the grinders are driven by less than 200 horsepower. The work which has been described in this publication indicates that a large amount of power to the grinder is desirable. In order to utilize a large amount of power, the stones must be operated under conditions of high speed and high pressure, or they must be of a larger size than those used at the present time. Efficiency of grinding wood can be greatly increased over present average commercial practice by the use of higher pressure, since this results in the reduction of the horsepower consumption per ton of product. There are cases, of course, where such practice would not be desirable. If sulphite is available at low cost and power is expensive, this condition would surely obtain; but if sulphite is expensive and power can be secured at a low figure it is undoubtedly more economical to use a large amount of power per ton of product and make economies in sulphite by virtue of the fact that with the large amount of power better and stronger ground-wood fiber can be obtained.

Economies in grinding, particularly as related to power, depend largely on the character of the material into which the ground wood is to be incorporated. For the manufacturing of such materials as wood-pulp board, as used in the wall-board industry, a long, coarse fiber is required, and this is most desirable, since fibers of this nature do not form as dense a sheet. There are, as a result, a large number of air spaces present which retard the passage of cold and sound. For the production of pulp of this nature pulp stones of coarse grit are required which are softer than those usually employed for the manufacturing of pulps for other purposes. When using a coarse stone, a longer fiber can be obtained at higher pressure than when a finer stone is utilized. Consequently, it is desirable in the production of this character of stock to choose the pulp stone carefully to secure the best results. The matter of efficiency as applied to the manufacturing of stock for any desired purpose hinges, to a large measure, on a careful selection of the pulp stone to be used.

It is common practice in ground-wood mills to use all of the pockets on the grinder in the production of the mechanical pulp. In other words, the total amount of power available for use on the grinder is used on all of the pockets and at the same time. Power can be saved and the efficiency of production increased to a marked extent by the utilization of a fewer than the total number of pockets of the grinder. If four-pocket grinders are used, it is more desirable to use three of the pockets continuously and keep the fourth for surplus to be employed at times when one of the other pockets is being filled or when binding or other troubles are being corrected. When all of the power available on a three-pocket grinder is used

on three pockets, due to the need of filling and frequent binding of the wood in the cells, the total power is used about 88 per cent of the time. In other words, only 88 per cent of the power is being used continuously. When two pockets on the same three-pocket grinder are used to consume the total power and the third is kept for surplus, as previously outlined, all of the power is in use approximately 93 to 95 per cent of the time. Here a saving can be made and the efficiency increased without the installation or use of any additional apparatus, simply by means of increasing the pressure on the grinder cylinders, since this would be necessary if all of the power were applied to two instead of the three pockets on that piece of apparatus. Of course, this does not have as great bearing on the increasing of efficiency when grinders are motor driven; but in case of the direct connection to turbines it will be seen that it is of great consequence.

When grinders are motor driven, the most efficient utilization of the power can be accomplished by the installation of a grinder-cylinder pressure-regulating valve controlled electrically from the bus bars, the idea being to increase the pressure when for any reason the power consumption falls off.

Not only does the increasing of pressure on the cylinders result in the lowering of the horsepower consumption per ton, but there is at higher pressures an increase in the quantity of pulp which can be secured from a cord of wood, and this is another vital factor in the study of the efficiency of production of mechanical pulp. In any case it seems desirable to study carefully the grinding conditions, the speed of the pulp stone, the pressure employed, and the character and grit of the stone in use, since it is to these factors that practically all losses and gains can be traced. The manipulation of the grinder and its feeding and operation by the grinderman are also of prime importance, since without careful watching the binding of the wood in the pockets or some like difficulty may result in reduction of the production from the grinder and also in the lowering on quality of the resultant product. Even with careful watching there are times while the grinder is apparently running satisfactorily when hardly three-fourths of the total power available for its use is being consumed, due to the binding of the wood in the pockets.

FUTURE SUPPLIES FOR THE GROUND-WOOD INDUSTRY.

Of the woods tested, Alpine fir, Engelmann spruce, lowland fir, lodgepole pine, balsam fir, white fir, amabilis fir, noble fir, Sitka spruce, western hemlock, and eastern hemlock all give promise of being suitable for the production of news-print papers. Color is here the chief consideration. An acceptable news-print paper can not be made from such a dark-colored pulp as that of tamarack. Yet this does not bar tamarack as a raw material for the ground-wood industry; it will give a thoroughly satisfactory grade of yellow manila.

Similarly, jack pine, which is also unsatisfactory for news-print purposes, can be used very effectively in the manufacture of box boards. When combined with a large proportion of sulphite any of the woods tested, except the hardwoods, should produce a satisfactory manila of a color other than white. For the manufacture of wood-pulp boards, jack pine, tamarack, loblolly pine, and larch, in addition to the woods mentioned as suitable for news print, should furnish acceptable material. When high color is desired, and a somewhat poorer one in the center of the board is not objectionable, black gum or poplar could be used as a liner, if combined with a small percentage of sulphite. In the manufacture of box boards from steamed wood all of the conifers tested could be utilized, except where the product was to be a strong container board. The spruces, however, will yield a steamed pulp suitable for almost every kind of container.

It will be noted that the great majority of the substitute woods are confined to the West, while the ground-wood industry at present obtains the bulk of its supply of raw material from the East. The industry, however, is really a frontier one. It must have a plentiful supply of wood and an abundance of cheap power, two things not readily obtainable in settled communities. As the regions in which the industry is now centered develop it will have to move on to other and less-settled ones. On the National Forests are immense quantities of many of the woods tested and abundant opportunities for power development.

APPENDIX A.

List of tables contained in Appendix A.

Species.	Grinding data.	Page.	Quality test data.	Page.
White spruce:	<i>Table No.</i>		<i>Table No.</i>	
Untreated.....	5	68	7	78
Cooked.....	6	74		
Balsam fir.....	8	86	33	124
Red fir.....	9	88	34	125
White fir.....	10	90	35	126
Alpine fir.....	11	92	36	127
Amabilis fir.....	12	93	37	128
Lowland fir.....	13	94	38	129
Noble fir.....	14	95	39	130
Hemlock.....	15	96	40	131
Western hemlock.....	16	98	41	131
Tamarack.....	17	99	42	132
Western larch.....	18	103	43	134
Lodgepole pine:				
Montana.....	19	104	44	135
California.....	20	106	45	136
Western yellow pine.....	21	108	46	137
Jack pine.....	22	110	47	138
Loblolly pine.....	23	112	48	139
White pine.....	24	114	49	140
Engelmann spruce:				
Montana.....	25	115	50	141
Colorado.....	26	116	51	142
Sitka spruce.....	27	117	52	143
White birch.....	28	118	53	144
Aspen.....	29	119	54	144
Black gum.....	30	120	55	145
Mixtures of wood.....	31	121	56	146
Woods for "commercial pulps".....	57	148	58	150

TABLE 5.—Grinder runs on white spruce.

Run No.	Stone.	Kind of burr.	Surface.	Number of pockets used.		Pressure on 14-inch cylinder.		Pressure per square inch of pocket area.		Revolutions per minute.		Peripheral speed.		Average horsepower to grinder.		Maximum horsepower to grinder.		Bone-dry pulp in 24 hours.		Solid rossed wood ground in 24 hours.		Weight per cubic foot bone-dry wood.		Average diameter of wood.		Moisture in wood.		Bone-dry pulp per 100 cubic feet solid rossed wood.		Efficiency of conversion.		Screenings per 100 cubic feet solid rossed wood, bone-dry.		Average temperature of grinding.		Horsepower divided by pressure $\times$ speed.	
				Lbs. per sq. in.	Lbs.	Lbs.	per minute.	Feet per minute.	Average horsepower to grinder.	Maximum horsepower to grinder.	Tons.	Horsepower per ton bone-dry pulp in 24 hours.	Cu. ft.	Lbs.	In.	Per cent.	Lbs.	Per cent.	Lbs.	Per cent.	Lbs.	Per cent.	Lbs.	Per cent.	Lbs.	Per cent.	Lbs.	Per cent.	Lbs.	Per cent.	Lbs.	Per cent.	Lbs.	Per cent.	Lbs.	Per cent.	Lbs.	Per cent.
1	Stone.	Kind of burr.	Surface.	3	40:50	175	2,445	403.0	4.988	80.8	386.2	29.1	28.4	27.00	28.90	2,480	87.4	17.2	172.6	171.0	175.5	171.0	175.5	171.0	175.5	171.0	175.5	171.0	175.5	171.0	175.5	171.0	175.5	171.0	175.5	171.0	175.5
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1	Stone.	Kind of burr.	Surface.	3	40:50	175	2,445	403.0	4.988	80.8	386.2	29.1	28.4	27.00	28.90	2,480	87.4	17.2	172.6	171.0	175.5	171.0	175.5	171.0	175.5	171.0	175.5	171.0	175.5	171.0	175.5	171.0	175.5	171.0	175.5	171.0	175.5
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1	Stone.	Kind of burr.	Surface.	3	40:50	175	2,445	403.0	4.988	80.8	386.2	29.1	28.4	27.00	28.90	2,480	87.4	17.2	172.6	171.0	175.5	171.0	175.5	171.0	175.5	171.0	175.5	171.0	175.5	171.0	175.5	171.0	175.5	171.0	175.5	171.0	175.5
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1	Stone.	Kind of burr.	Surface.	3	40:50	175	2,445	403.0	4.988	80.8	386.2	29.1	28.4	27.00	28.90	2,480	87.4	17.2	172.6	171.0	175.5	171.0	175.5	171.0	175.5	171.0	175.5	171.0	175.5	171.0	175.5	171.0	175.5	171.0	175.5	171.0	175.5
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1	Stone.	Kind of burr.	Surface.	3	40:50	175	2,445	403.0	4.988	80.8	386.2	29.1	28.4	27.00	28.90	2,480	87.4	17.2	172.6	171.0	175.5	171.0	175.5	171.0	175.5	171.0	175.5	171.0	175.5	171.0	175.5	171.0	175.5	171.0	175.5	171.0	175.5
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1	Stone.	Kind of burr.	Surface.	3	40:50	175	2,445	403.0	4.988	80.8	386.2	29.1	28.4	27.00	28.90	2,480	87.4	17.2	172.6	171.0	175.5	171.0	175.5	171.0	175.5	171.0	175.5	171.0	175.5	171.0	175.5	171.0	175.5	171.0	175.5	171.0	175.5
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1	Stone.	Kind of burr.	Surface.	3	40:50	175	2,445	403.0	4.988	80.8	386.2	29.1	28.4	27.00	28.90	2,480	87.4	17.2	172.6	171.0	175.5	171.0	175.5	171.0	175.5	171.0	175.5	171.0	175.5	171.0	175.5	171.0	175.5	171.0	175.5	171.0	175.5
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1	Stone.	Kind of burr.	Surface.	3	40:50	175	2,445	403.0	4.988	80.8	386.2	29.1	28.4	27.00	28.90	2,480	87.4	17.2	172.6	171.0	175.5	171.0	175.5	171.0	175.5	171.0	175.5	171.0	175.5	171.0	175.5	171.0	175.5	171.0	175.5	171.0	175.5
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1	Stone.	Kind of burr.	Surface.	3	40:50	175	2,445	403.0	4.988	80.8	386.2	29.1	28.4	27.00	28.90	2,480	87.4	17.2	172.6	171.0	175.5	171.0	175.5	171.0	175.5	171.0	175.5	171.0	175.5	171.0	175.5	171.0	175.5	171.0	175.5	171.0	175.5
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1	Stone.	Kind of burr.	Surface.	3	40:50	175	2,445	403.0	4.988	80.8	386.2	29.1	28.4	27.00	28.90	2,480	87.4	17.2	172.6	171.0	175.5	171.0	175.5	171.0	175.5	171.0	175.5	171.0	175.5	171.0	175.5	171.0	175.5	171.0	175.5	171.0	175.5
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1	Stone.	Kind of burr.	Surface.	3	40:50	175	2,445	403.0	4.988	80.8	386.2	29.1	28.4	27.00	28.90	2,480	87.4	17.2	172.6	171.0	175.5	171.0	175.5	171.0	175.5	171.0	175.5	171.0	175.5	171.0	175.5	171.0	175.5	171.0	175.5	171.0	175.5
1																																					
1																																					
1	Stone.	Kind of burr.	Surface.	3	40:50	175	2,445	403.0	4.988	80.8	386.2	29.1	28.4	27.00	28.90	2,480	87.4	17.2	172.6	171.0	175.5	171.0	175.5	171.0	175.5	171.0	175.5	171.0	175.5	171.0	175.5	171.0	175.5	171.0	175.5	171.0	175.5
1																																					
1																																					
1	Stone.	Kind of burr.	Surface.	3	40:50	175	2,445	403.0	4.988	80.8	386.2	29.1	28.4	27.00	28.90	2,480	87.4	17.2	172.6	171.0	175.5	171.0	175.5	171.0	175.5	171.0	175.5	171.0	175.5	171.0	175.5	171.0	175.5	171.0	175.5	171.0	175.5
1																																					
1																																					
1	Stone.	Kind of burr.	Surface.	3	40:50	175	2,445	403.0	4.988	80.8	386.2	29.1	28.4	27.00	28.90	2,480	87.4	17.2	172.6	171.0	175.5	171.0	175.5	171.0	175.5	171.0	175.5	171.0	175.5	171.0	175.5	171.0	175.5	171.0	175.5	171.0	175.5
1																																					
1																																					
1	Stone.	Kind of burr.	Surface.	3	40:50	175	2,445	403.0	4.988	80.8	386.2	29.1	28.4	27.00	28.90	2,480	87.4	17.2	172.6	171.0	175.5	171.0	175.5	171.0	175.5	171.0	175.5	171.0	175.5	171.0	175.5	171.0	175.5	171.0	175.5	171.0	175.5
1																																					
1																																					
1	Stone.	Kind of burr.	Surface.	3	40:50	175	2,445	403.0	4.988	80.8	386.2	29.1	28.4	27.00	28.90	2,480	87.4	17.2	172.6	171.0	175.5	171.0	175.5	171.0	175.5	171.0	175.5	171.0	175.5	171.0	175.5	171.0	175.5	171.0	175.5	171.0	175.5
1																																					
1																																					
1	Stone.	Kind of burr.	Surface.	3	40:50	175	2,445	403.0	4.988	80.8	386.2	29.1	28.4	27.00	28.90	2,480	87.4	17.2	172.6	171.0	175.5	171.0	175.5	171.0	175.5	171.0	175.5	171.0	175.5	171.0	175.5	171.0	175.5	171.0	175.5	171.0	175.5
1																																					
1																																					
1	Stone.	Kind of burr.	Surface.	3	40:50	175	2,445	403.0	4.988	80.8	386.2	29.1	28.4	27.00	28.90	2,480	87.4	17.2	172.6	171.0	175.5	171.0	175.5	171.0	175.5	171.0	175.5	171.0	175.5	171.0	175.5	171.0	175.5	171.0	175.5	171.0	175.5
1																																					
1																																					
1	Stone.	Kind of burr.	Surface.	3	40:50	175	2,445	403.0	4.988	80.8	386.2	29.1	28.4	27.00	28.90	2,480	87.4	17.2	172.6	171.0	175.5	171.0	175.5	171.0	175.5	171.0	175.5	171.0	175.5	171.0	175.5	171.0	175.5	171.0	175.5	171.0	175.5
1																																					
1																																					
1	Stone.	Kind of burr.	Surface.																																		

1 92	Diamond point, cut 6 to 10 inch.	2 100	41.0	250	3,452	650.0	723	Qualitative run; no production data.	27.51	62	27.47	126.5	0.0460
1 93	do.	2 100	41.0	250	3,452	576.5	286		27.51	62	27.47	136.0	0.0096
1 94	Spral, cut 6 to inch.	2 100	41.0	250	3,435	552.5	653		27.51	62	27.47	107.6	0.0097
1 95	do.	2 100	41.0	250	3,435	552.5	653		27.51	62	27.47	107.6	0.0097
1 96	Straight, cut 3 to inch; spiral, cut 12 to inch.	2 40	16.4	200	2,748	330.0	378		27.51	5	27.47	113.6	0.0826
1 97	do.	2 40	16.4	200	2,748	330.0	378		27.51	5	27.47	113.6	0.0826
1 98	do.	2 40	16.4	200	2,748	330.0	378		27.51	5	27.47	113.6	0.0826
1 99	do.	2 40	16.4	200	2,748	330.0	378		27.51	5	27.47	113.6	0.0826
1 100	do.	2 40	16.4	200	2,748	330.0	378		27.51	5	27.47	113.6	0.0826
1 101	do.	2 40	16.4	200	2,748	330.0	378		27.51	5	27.47	113.6	0.0826
1 102	do.	2 40	16.4	200	2,748	330.0	378		27.51	5	27.47	113.6	0.0826
1 103	do.	2 40	16.4	200	2,748	330.0	378		27.51	5	27.47	113.6	0.0826
1 104	do.	2 40	16.4	200	2,748	330.0	378		27.51	5	27.47	113.6	0.0826
1 105	do.	2 40	16.4	200	2,748	330.0	378		27.51	5	27.47	113.6	0.0826
1 106	do.	2 40	16.4	200	2,748	330.0	378		27.51	5	27.47	113.6	0.0826
1 107	do.	2 40	16.4	200	2,748	330.0	378		27.51	5	27.47	113.6	0.0826
1 108	do.	2 40	16.4	200	2,748	330.0	378		27.51	5	27.47	113.6	0.0826
1 109	do.	2 40	16.4	200	2,748	330.0	378		27.51	5	27.47	113.6	0.0826
1 110	do.	2 40	16.4	200	2,748	330.0	378		27.51	5	27.47	113.6	0.0826
1 111	do.	2 40	16.4	200	2,748	330.0	378		27.51	5	27.47	113.6	0.0826
1 112	do.	2 40	16.4	200	2,748	330.0	378		27.51	5	27.47	113.6	0.0826
1 113	do.	2 40	16.4	200	2,748	330.0	378		27.51	5	27.47	113.6	0.0826
1 114	do.	2 40	16.4	200	2,748	330.0	378		27.51	5	27.47	113.6	0.0826
1 115	do.	2 40	16.4	200	2,748	330.0	378		27.51	5	27.47	113.6	0.0826
1 116	do.	2 40	16.4	200	2,748	330.0	378		27.51	5	27.47	113.6	0.0826
1 117	do.	2 40	16.4	200	2,748	330.0	378		27.51	5	27.47	113.6	0.0826
1 118	do.	2 40	16.4	200	2,748	330.0	378		27.51	5	27.47	113.6	0.0826
1 119	do.	2 40	16.4	200	2,748	330.0	378		27.51	5	27.47	113.6	0.0826
1 120	do.	2 40	16.4	200	2,748	330.0	378		27.51	5	27.47	113.6	0.0826
1 121	do.	2 40	16.4	200	2,748	330.0	378		27.51	5	27.47	113.6	0.0826
1 122	do.	2 40	16.4	200	2,748	330.0	378		27.51	5	27.47	113.6	0.0826
1 123	do.	2 40	16.4	200	2,748	330.0	378		27.51	5	27.47	113.6	0.0826
1 124	do.	2 40	16.4	200	2,748	330.0	378		27.51	5	27.47	113.6	0.0826
1 125	do.	2 40	16.4	200	2,748	330.0	378		27.51	5	27.47	113.6	0.0826
1 126	do.	2 40	16.4	200	2,748	330.0	378		27.51	5	27.47	113.6	0.0826
1 127	do.	2 40	16.4	200	2,748	330.0	378		27.51	5	27.47	113.6	0.0826
1 128	do.	2 40	16.4	200	2,748	330.0	378		27.51	5	27.47	113.6	0.0826
1 129	do.	2 40	16.4	200	2,748	330.0	378		27.51	5	27.47	113.6	0.0826
1 130	do.	2 40	16.4	200	2,748	330.0	378		27.51	5	27.47	113.6	0.0826
1 131	do.	2 40	16.4	200	2,748	330.0	378		27.51	5	27.47	113.6	0.0826
1 132	do.	2 40	16.4	200	2,748	330.0	378		27.51	5	27.47	113.6	0.0826
1 133	do.	2 40	16.4	200	2,748	330.0	378		27.51	5	27.47	113.6	0.0826
1 134	do.	2 40	16.4	200	2,748	330.0	378		27.51	5	27.47	113.6	0.0826
1 135	do.	2 40	16.4	200	2,748	330.0	378		27.51	5	27.47	113.6	0.0826
1 136	do.	2 40	16.4	200	2,748	330.0	378		27.51	5	27.47	113.6	0.0826
1 137	do.	2 40	16.4	200	2,748	330.0	378		27.51	5	27.47	113.6	0.0826
1 138	do.	2 40	16.4	200	2,748	330.0	378		27.51	5	27.47	113.6	0.0826
1 139	do.	2 40	16.4	200	2,748	330.0	378		27.51	5	27.47	113.6	0.0826
1 140	do.	2 40	16.4	200	2,748	330.0	378		27.51	5	27.47	113.6	0.0826
1 141	do.	2 40	16.4	200	2,748	330.0	378		27.51	5	27.47	113.6	0.0826
1 142	do.	2 40	16.4	200	2,748	330.0	378		27.51	5	27.47	113.6	0.0826
1 143	do.	2 40	16.4	200	2,748	330.0	378		27.51	5	27.47	113.6	0.0826
1 144	do.	2 40	16.4	200	2,748	330.0	378		27.51	5	27.47	113.6	0.0826
1 145	do.	2 40	16.4	200	2,748	330.0	378		27.51	5	27.47	113.6	0.0826
1 146	do.	2 40	16.4	200	2,748	330.0	378		27.51	5	27.47	113.6	0.0826
1 147	do.	2 40	16.4	200	2,748	330.0	378		27.51	5	27.47	113.6	0.0826
1 148	do.	2 40	16.4	200	2,748	330.0	378		27.51	5	27.47	113.6	0.0826
1 149	do.	2 40	16.4	200	2,748	330.0	378		27.51	5	27.47	113.6	0.0826
1 150	do.	2 40	16.4	200	2,748	330.0	378		27.51	5	27.47	113.6	0.0826
1 151	do.	2 40	16.4	200	2,748	330.0	378		27.51	5	27.47	113.6	0.0826
1 152	do.	2 40	16.4	200	2,748	330.0	378		27.51	5	27.47	113.6	0.0826
1 153	do.	2 40	16.4	200	2,748	330.0	378		27.51	5	27.47	113.6	0.0826
1 154	do.	2 40	16.4	200	2,748	330.0	378		27.51	5	27.47	113.6	0.0826
1 155	do.	2 40	16.4	200	2,748	330.0	378		27.51	5	27.47	113.6	0.0826
1 156	do.	2 40	16.4	200	2,748	330.0	378		27.51	5	27.47	113.6	0.0826
1 157	do.	2 40	16.4	200	2,748	330.0	378		27.51	5	27.47	113.6	0.0826
1 158	do.	2 40	16.4	200	2,748	330.0	378		27.51	5	27.47	113.6	0.0826
1 159	do.	2 40	16.4	200	2,748	330.0	378		27.51	5	27.47	113.6	0.0826
1 160	do.	2 40	16.4	200	2,748	330.0	378		27.51	5	27.47	113.6	0.0826
1 161	do.	2 40	16.4	200	2,748	330.0	378		27.51	5	27.47	113.6	0.0826
1 162	do.	2 40	16.4	200	2,748	330.0	378		27.51	5	27.47	113.6	0.0826
1 163	do.	2 40	16.4	200	2,748	330.0	378		27.51	5	27.47	113.6	0.0826
1 164	do.	2 40	16.4	200	2,748	330.0	378		27.51	5	27.47	113.6	0.0826
1 165	do.	2 40	16.4	200	2,748	330.0	378		27.51	5	27.47	113.6	0.0826
1 166	do.	2 40	16.4	200	2,748	330.0	378		27.51	5	27.47	113.6	0.0826
1 167	do.	2 40	16.4	200	2,748	330.0	378		27.51	5	27.47	113.6	0.0826
1 168	do.	2 40	16.4	200	2,748	330.0	378		27.51	5	27.47	113.6	0.0826
1 169	do.	2 40	16.4	200	2,748	330.0	378		27.51	5	27.47	113.6	0.0826
1 170	do.	2 40	16.4	200	2,748	330.0	378		27.51	5	27.47	113.6	0.0826
1 171	do.	2 40	16.4	200	2,748	330.0	378		27.51	5	27.47	113.6	0.0826
1 172	do.	2 40	16.4	200	2,748	330.0	378		27.51	5	27.47	113.6	0.0826
1 173	do.	2 40	16.4	200	2,748	330.0	378		27.51	5	27.47	113.6	0.0826
1 174	do.	2 40	16.4	200	2,748	330.0	378		27.51	5	27.47	113.6	0.0826
1 175	do.	2 40	16.4	200	2,748	330.0	378		27.51	5	27.47	113.6	0.0826
1 176	do.	2 40	16.4	200	2,748	330.0	378		27.51	5	27.47	113.6	0.0826
1 177	do.	2 40	16.4	200	2,748	330.0	378		27.51	5	27.47	113.6	0.0826
1 178	do.	2 40	16.4	200	2,748	330.0	378		27.51	5	27.47	113.6	0.0826
1 179	do.	2 40	16.4	200	2,748	330.0	378		27.51	5	27.47	113.6	0.0826
1 180	do.	2 40	16.4	200	2,748	330.0	378		27.51	5	27.47	113.6	0.0826
1 181	do.	2 40	16.4	200	2,748	330.0	378		27.51	5	27.47	113.6	0.0826
1 182	do.	2 40	16.4	200	2,748	330.0	378		27.51	5	27.47	113.6	0.0826
1 183	do.	2 40	16.4	200	2,748	330.0	378		27.51	5	27.47	113.6	0.0826
1 184	do.	2 40	16.4	200	2,748	330.0	378		27.51	5	27.47	113.6	0.0826
1 185	do.	2 40	16.4	200	2,748	330.0	378		27.51	5	27.47	113.6	0.0826
1 186	do.	2 40	16.4	200	2,748	330.0	378		27.51	5	27.47	113.6	0.0826
1 187	do.	2 40	16.4	200	2,748	330.0	378		27.51	5	27.47	113.6	0.0826
1 188	do.	2 40	16.4	200	2,748	330.0	378		27.51	5	27.47	113.6	0.0826
1 189	do.	2 40	16.4	200	2,748	330.0	378		27.51	5	27.47	113.6	0.0826
1 190	do.	2 40	16.4	200	2,748	330.0	378		27.51	5			

Seasoned wood used.

2 Green wood used

TABLE 5.—Grinder runs on white spruce—Continued.

Run No.	Kind of burr.	Stone.	Surface.	Number of pockets used.	Pressure on 14-inch cylinder.	Pressure per square inch of pocket area.	Revolutions per minute.	Peripheral speed.	Average horsepower to grinder.	Maximum horsepower to grinder.	Bone-dry pulp in 24 hours.	Horsepower per ton bone-dry pulp in 24 hours.	Solid rossed wood ground in 24 hours.	Weight per cubic foot bone-dry wood.	Average diameter of wood.	Moisture in wood.	Bone-dry pulp per 100 cubic feet solid rossed wood.	Efficiency of conversion.	Screens per 100 cubic foot solid rossed wood, bone-dry.	Average temperature of grinding.	Horsepower divided by pressure $\times$ speed.
1160	Straight, cut 3 to inch; spiral, cut 10 to inch.	Stone.	Same surface.	3	Lbs. 30	Lbs. 12.3	250	Feet per minute. 3,427	308.0	338	Tons. 2,250	136.8	Cu. ft. 190.3	Lbs. 26.48	In. 5.1	Per cent. 31.12	Lbs. 2,365	Per cent. 89.4	Lbs. 11.37	$^{\circ}$ F. 158.3	0.00730
1161	do.		do.	3	35	14.35	214	2,936	328.0	368	2,210	148.2	191.6	26.48	4.1	31.12	2,310	87.1	9.10	178.2	0.00779
1162	do.		do.	3	40	16.4	188	2,530	317.0	350	2,425	130.8	206.0	26.48	5.0	31.12	2,350	88.7	9.81	169.3	0.00750
1163	do.		do.	3	45	18.45	167	2,290	339.0	380	2,825	120.0	230.0	26.48	5.3	31.12	2,455	92.6	13.26	166.6	0.0802
1164	do.		do.	3	50	20.5	150	2,056	323.0	361	2,445	132.1	204.5	26.48	5.3	31.12	2,385	90.1	11.62	158.2	0.00767
1165	do.		do.	3	55	22.55	136	1,867	310.0	347	2,265	136.7	196.0	26.48	5.3	31.12	2,310	87.1	11.70	165.1	0.00736
1166	do.		do.	3	60	24.65	125	1,714	323.0	386	2,775	116.5	68.7	26.48	4.5	31.12	2,350	88.7	16.45	155.7	0.00764
1177	Diamond point, cut 8 to inch.		Same as No. 176.	2	20	8.2	225	3,085	157.5	194	760	207.0	68.7	27.54	4.1	27.98	2,210	80.3	10.75	161.2	0.06622
1178	do.		Same surface.	2	40	16.4	225	3,085	280.0	314	2,240	125.0	193.0	27.54	4.3	27.98	2,315	84.0	9.02	160.0	0.05533
1179	do.		do.	2	60	24.65	225	3,085	387.0	455	4,095	94.5	342.0	27.54	4.4	27.98	2,390	86.9	10.27	137.5	0.0508
1180	do.		do.	2	80	32.8	225	3,085	485.0	530	5,545	87.5	468.0	27.54	5.0	27.98	2,370	86.0	10.90	126.4	0.0479
1181	do.		do.	2	100	40.0	225	3,085	563.0	630	7,450	73.5	645.0	27.54	5.3	27.98	2,310	83.9	16.57	126.7	0.0445
1210	Spiral, cut 8 to inch.		Stone dressed.	3	50	20.5	200	2,728	410.0	469	1,260	323.0	Axis of wood was perpendicular to axis of stone.	No production data.	6.1	32.24	2,400	94.6	14.65	146.0	0.0470
1222	Straight, cut 3 to inch; spiral, cut 12 to inch.	Stone.	Same as lowland fir No. 17.	2	80	32.8	225	3,069	474.0	566	6,610	71.6	551.0	25.37	4.3	34.83	2,365	92.2	7.10	158.0	0.0569
1243	Spiral, cut 8 to inch; straight, cut 10 to inch.		Same surface.	2	40	16.4	175	2,348	219.0	263	1,750	125.0	148.0	25.63	4.3	34.83	2,365	92.2	7.10	158.0	0.0569
1244	do.		do.	2	60	24.65	175	2,348	306.0	346	3,145	97.3	261.0	25.63	4.8	34.83	2,412	94.0	12.10	142.0	0.0528
1245	do.		do.	2	80	32.8	175	2,348	370.0	450	4,375	84.5	360.0	25.63	5.0	34.83	2,430	94.8	13.10	142.0	0.0480
1246	do.		do.	2	100	40.0	175	1,342	212.0	238	2,175	97.4	181.0	25.63	4.4	34.83	2,410	94.0	10.60	145.0	0.0640
1247	do.		do.	2	60	24.65	250	3,355	411.0	465	3,870	106.0	315.0	25.63	4.4	34.83	2,460	96.0	9.10	150.0	0.0497
1248	do.		Stone dressed.	2	60	24.65	175	2,348	316.0	372	4,740	66.5	489.0	25.63	4.4	34.83	2,460	88.1	8.2	96.0	0.0545
1249	do.		do.	2	60	24.65	175	2,348	321.0	380	1,700	189.0	189.0	25.63	5.1	34.83	1,803	70.4	4.9	79.0	0.0554
1250	do.		do.	2	60	24.65	175	2,348	312.0	400	2,080	153.7	187.0	25.63	5.1	34.83	2,170	84.6	7.6	151.0	0.0538
1251	do.		Same surface.	2	60	24.65	175	2,348	304.0	369	2,036	146.0	193.0	25.63	4.4	34.83	2,150	83.9	10.4	170.0	0.0524
1252	do.	Stone.	do.	3	50	20.50	225	3,020	436.0	531	2,025	215.0	191.0	25.50	5.3	33.1	2,120	82.6	8.2	176.0	0.0705
1253	do.		do.	3	50	20.50	225	3,020	437.0	550	2,560	178.5	236.0	25.50	5.3	33.1	2,260	88.1	6.4	154.0	0.0730
1254	do.		do.	3	50	20.50	225	3,020	527.0	641	2,570	205.0	242.0	25.50	5.3	33.1	2,210	82.6	.....	80.0	0.0852

255	do.....	3	40	16.40	175	2,348	258.0	314	2.845	90.6	391.0	18.60	121	30.80	1,455	78.3	12.3	130.0	.00670
256	do.....	3	40	16.40	175	2,348	290.0	342	2.250	129.0	194.0	25.83	488	29.66	2,320	89.9	14.2	147.0	.00753
1257	Straight, cut 3 to inch; spiral, cut 12 to inch.	3	20	8.20	175	2,425	176.0	204	1.190	148.0	111.0	24.36	424	28.73	2,140	88.0	22.5	170.0	.00885
1258	do.....	3	40	16.40	175	2,425	331.0	415	3.450	96.0	318.0	24.36	424	28.73	2,170	89.1	35.9	156.0	.00832
1259	do.....	3	60	24.65	175	2,425	514.0	565	7.460	68.8	670.0	24.36	424	28.73	2,230	91.6	74.0	132.0	.00859
1260	do.....	3	40	16.40	100	1,387	235.0	277	2.410	97.5	220.0	24.36	424	28.73	2,185	88.9	32.6	157.0	.01032
1261	do.....	3	40	16.40	150	2,080	338.0	392	4.270	83.6	395.0	24.36	424	28.73	2,160	88.8	56.6	150.0	.01049
1262	do.....	3	40	16.40	200	2,774	428.0	478	4.820	88.3	433.0	24.36	424	28.73	2,220	91.2	30.0	145.0	.00936
1263	do.....	3	40	16.40	250	3,468	490.0	522	6.385	76.7	573.0	24.36	424	28.73	2,222	91.3	34.9	140.0	.00861
1264	do.....	2	60	24.65	225	3,120	418.0	459	7.850	53.2	814.0	24.36	424	28.73	1,930	78.3	43.9	131.0	.00743
1276	do.....	2	20	8.20	225	3,120	151.0	198	1.750	86.0	117.0	25.11	424	28.88	2,380	94.8	11.5	133.0	.00390
1277	do.....	2	40	16.40	225	3,120	310.0	353	4.295	72.2	418.0	25.11	424	28.88	1,920	76.5	27.3	128.0	.00606
1278	do.....	2	60	24.65	225	3,120	469.0	530	9.040	52.0	769.0	25.11	424	28.88	2,854	92.8	32.4	127.0	.00909
1279	do.....	2	80	32.80	225	3,120	512.0	606	11.800	46.0	982.0	25.11	424	28.88	2,400	95.6	31.0	122.0	.00730
1280	do.....	3	30	12.32	200	2,774	296.0	361	3.580	82.7	304.0	25.11	424	28.88	2,360	91.0	9.1	72.0	.00867
1281	do.....	3	30	12.32	200	2,774	312.0	370	3.673	85.0	310.0	25.11	424	28.88	2,360	94.0	11.4	133.0	.00943
1282	do.....	3	30	12.32	200	2,774	303.0	364	3.600	103.0	260.0	25.11	424	28.88	2,300	91.6	19.8	168.0	.00902

¹ Seasoned wood used.² Partially decayed wood used.

Runs 257-282 were run on a coarse-grit stone.

TABLE 6.—Grinder runs on spruce wood—cooked prior to grinding.

Grinder run No.	Cooking treatment.		Kind of burr.	Stone.	Number of pockets used.	Pressure on 14-inch cylinder.	Revolutions per minute.	Average horsepower to grinder.	Maximum horsepower to grinder.	Bone-dry pulp in 24 hours.	Horsepower per ton bone-dry pulp in 24 hours.	Solid rossed wood ground in 24 hours.	Weight per cubic foot of wood (bone-dry).	Average diameter of wood.	Moisture in wood.	Pulp bone-dry per 100 cubic feet of solid rossed wood.	Efficiency of conversion.	Screenings bone-dry per 100 cubic feet solid rossed wood.	Average temperature of grinding.	Horsepower divided by pressure × speed.
	Kind of cook.	Duration of cook.																		
	Hrs.	Lbs.				Lbs. per sq. in.			Tons.	Cu. ft.	Lbs.			Ins.	Per cent.	Lbs.	Per cent.	Lbs.	° F.	
151	Steamed.	8	60	Same as for tamarack No. 23.	3	40	200	326	372	3,130	104.0	340.0	22.96	92	39.08	1,840	80.2	18.47	156.6	0.00719
157	Boiled 2	4	60	Same as for spruce No. 56.	3	40	200	325	394	3,380	99.2	296.0	27.11	54	25.31	2,283	84.4	23.60	156.0	.00739
172	Steamed.	8	60	Same as for western yellow pine No. 3.	3	40	200	301	358	2,250	133.9	250.0	25.06	80	30.36	1,800	71.9	16.15	166.4	.00664
173	do.	2	60	Same as for white birch No. 1.	3	40	200	353	415	2,800	126.0	264.0	26.84	58	30.73	2,122	79.0	19.25	164.1	.00777
175	do.	4	60	do.	3	20	175	172	212	2,784	220.0	79.2	26.06	5	31.29	1,980	70.0	12.48	171.0	.00871
178	do.	4	60	Same as for spruce No. 76.	3	40	175	299	349	2,155	138.8	208.5	27.48	6	28.61	2,066	70.2	18.19	158.2	.00755
179	do.	4	60	do.	3	60	175	373	449	2,935	127.1	292.0	27.14	6	28.83	2,013	74.2	23.09	149.4	.00826
397	do.	6	60	do.	2	20	225	153	189	1,803	84.9	197.8	26.06	28	36.51	1,853	68.4	10.98	131.5	.00605
398	do.	6	60	Stone dressed.	2	20	225	230	272	3,365	68.1	352.0	27.19	7	39.66	1,910	70.3	18.82	121.1	.00452
399	do.	6	60	Same surface.	2	20	225	308	360	4,020	76.7	426.0	27.19	7	39.66	1,883	69.4	27.37	120.2	.00404
3100	do.	6	60	do.	2	20	225	369	401	4,655	79.1	496.0	27.19	61	33.66	1,876	69.0	34.00	125.1	.00364
3101	do.	6	60	do.	2	20	225	420	510	4,615	90.9	487.0	27.19	61	33.66	1,896	69.7	45.55	128.4	.00332
3102	do.	6	60	Stone dressed.	2	20	200	280	320	3,075	91.1	376.0	25.06	61	44.00	1,636	65.3	18.57	125.0	.00621
3103	do.	6	20	Same surface.	3	40	200	323	382	4,195	79.1	378.0	27.81	61	26.22	2,219	79.7	12.28	128.7	.00736
3104	do.	6	20	do.	3	40	200	323	393	4,210	76.7	390.0	27.81	5	26.22	2,160	77.6	16.86	137.0	.00716
3105	do.	6	20	do.	3	40	200	327	364	3,995	81.8	422.0	27.81	5	26.22	2,081	76.3	17.81	137.8	.00710
3106	do.	8	20	do.	3	40	200	320	382	3,595	89.1	344.0	27.30	5	27.56	2,070	75.8	19.93	136.4	.00716
3107	do.	12	20	do.	3	40	200	323	398	3,565	90.6	346.0	27.30	5	27.56	2,263	85.9	16.53	144.9	.00681
3108	do.	4	40	do.	3	40	200	339	393	3,810	89.0	337.0	26.50	5	29.88	2,170	82.0	21.80	134.0	.00681
3109	do.	4	40	do.	3	40	200	307	363	3,705	82.9	342.0	26.50	5	29.88	2,105	79.5	15.80	142.2	.00682
3110	do.	6	40	do.	3	40	200	285	342	3,027	97.4	278.0	26.50	5	29.88	2,000	75.5	12.98	139.5	.00610
3111	do.	8	40	do.	3	40	200	275	323	3,037	90.6	304.0	26.50	5	29.88	1,998	75.4	10.40	143.7	.00639
3113	do.	12	40	Same as for spruce No. 112.	3	40	200	288	342	2,885	96.5	299.0	26.50	5	29.88	2,080	76.5	10.96	137.9	.00632
3115	do.	2	60	Same as for spruce No. 114.	3	40	200	284	368	3,260	90.1	314.0	27.09	5	30.66	2,850	73.2	19.30	140.8	.00559
3116	do.	4	60	Same surface.	3	40	200	252	308	2,475	101.9	270.0	25.05	6	40.34	1,850	68.8	11.13	138.1	.00631
3117	do.	6	60	do.	3	40	200	271	328	2,640	106.7	295.0	25.05	6	40.34	1,722	68.3	14.76	138.6	.00627
3118	do.	8	60	do.	3	40	200	283	329	2,775	102.0	325.0	25.05	6	40.34	1,710	68.3	14.76	138.6	.00627

12	60	do.	do.	1199	40	2009	2771	3299	2.8051	98.8	336.01	25.05	6	40	34	1.6701	68.7	13.10	138.6	0.0051	
4	60	do.	Same as for spruce No. 129.	1130	60	225	445	597	3.110	96.7	482.0	28.01	5	28	09	2.134	75.9	43.70	143.6	0.0050	
4	60	do.	Same surface.	1131	60	225	378	433	3.807	99.3	362.0	27.66	4	28	08	2.100	75.9	43.70	143.6	0.0048	
4	60	do.	do.	1132	60	225	230	298	1.977	116.3	186.8	27.66	4	28	08	2.118	76.5	10.55	149.3	0.0048	
6	60	do.	Same as for spruce No. 166.	1167	60	225	143	175	1.476	327.0	50.8	26.15	6	30	19	1.720	76.9	8.54	150.0	0.0054	
6	60	do.	Same surface.	1168	60	225	231	285	1.470	134.0	133.9	26.15	5	30	19	1.910	73.1	13.0	132.0	0.0462	
6	60	do.	do.	1169	60	225	318	362	2.845	111.7	280.0	26.15	5	30	19	2.030	77.6	21.2	132.0	0.0417	
6	60	do.	do.	1170	60	225	407	480	3.480	117.0	352.0	26.15	4	30	19	1.980	75.8	26.05	139.0	0.0402	
6	60	do.	do.	1171	100	225	440	517	3.505	123.5	368.0	26.15	4	30	19	1.910	73.0	24.3	139.0	0.0348	
6	60	do.	Stone dressed.	1172	20	225	143	179	.748	191.1	82.6	26.52	4	29	36	1.810	68.2	6.31	153.0	0.00765	
6	60	do.	do.	1173	40	225	240	279	1.975	121.3	202.0	26.52	4	29	36	1.945	73.4	9.5	135.7	0.0174	
6	60	do.	Same surface.	1174	60	225	313	376	2.840	110.1	293.0	26.52	4	29	36	1.912	73.3	15.4	138.7	0.0111	
6	60	do.	do.	1175	60	225	352	431	3.195	110.0	327.0	26.52	4	29	36	1.933	73.7	24.9	137.0	0.00348	
6	60	do.	do.	1176	60	225	338	493	3.443	114.0	336.0	26.52	5	21	56	2.018	77.3	28.2	140.8	0.00314	
6	60	do.	Stone dressed.	1182	20	225	167	211	1.170	142.4	128.8	26.55	4	25	96	1.818	67.6	14.78	130.6	0.00535	
6	60	do.	Same surface.	1183	60	225	271	318	2.680	101.0	282.0	26.89	5	23	96	1.900	70.7	21.70	131.0	0.00355	
6	60	do.	do.	1184	60	225	350	402	3.423	102.2	377.0	26.89	5	23	96	1.925	70.2	31.80	107.0	0.00460	
6	60	do.	do.	1185	60	225	345	403	4.130	83.5	411.0	26.85	5	23	96	2.010	74.9	31.8	119.0	0.0143	
6	60	do.	do.	1186	60	225	400	490	4.930	81.0	501.0	26.85	4	23	96	1.983	73.2	50.9	115.0	0.00395	
6	60	do.	do.	1187	100	225	432	532	5.230	86.1	541.0	26.85	4	23	96	1.940	72.2	60.5	112.0	0.00358	
6	60	do.	do.	1188	60	100	163	202	1.591	102.2	166.0	26.65	5	30	30	1.920	72.0	27.10	106.5	0.0481	
6	60	do.	do.	1189	60	60	150	233	272	2.375	98.2	26.85	5	25	96	1.803	67.1	27.5	107.4	0.0440	
6	60	do.	do.	1190	60	60	200	324	369	3.820	84.8	309.0	26.85	4	25	96	1.912	71.1	41.1	118.8	0.0479
6	60	do.	do.	1191	60	60	270	376	435	5.120	73.4	533.0	26.85	4	25	96	1.922	71.5	30.55	107.0	0.0445
12	60	do.	Stone dressed.	1192	60	50	225	321	410	2.510	124.0	287.0	25.14	7	28	70	1.750	69.6	11.9	120.9	0.0047
8	60	do.	Same surface.	1193	60	50	225	329	421	2.425	135.7	297.0	25.14	6	28	70	1.690	61.3	14.53	136.7	0.00222
8	60	do.	do.	1194	60	50	225	336	445	2.126	167.2	238.0	25.14	6	28	70	1.700	71.3	15.20	143.3	0.00265
6	60	do.	do.	1195	60	50	225	338	441	2.125	168.3	218.0	25.14	5	31	14	1.942	77.1	14.69	140.7	0.00469
6	60	do.	do.	1196	60	50	225	338	453	2.032	172.1	247.0	25.14	6	32	30	1.669	66.1	13.81	145.6	0.00500
2	60	do.	do.	1197	60	50	225	378	460	2.047	184.8	185.0	25.14	0	31	11	2.212	88.0	14.08	161.9	0.00569
6	60	do.	do.	1198	60	50	225	415	515	2.473	182.6	233.74	24.85	5	35	13	2.078	87.4	9.55	172.0	0.00715
3	60	do.	Same as for western hemlock No. 14.	1199	60	225	348	416	3.495	93.6	321.0	24.85	4	34	36	2.178	87.5	17.52	112.6	0.00310	
8	25	do.	Same surface.	1200	60	225	363	413	3.455	105.0	320.0	24.85	4	34	36	2.160	86.9	16.33	120.0	0.0479	
6	25	do.	do.	1201	60	225	354	400	3.490	101.4	305.0	24.85	4	34	36	2.285	92.0	15.46	115.0	0.0467	
6	25	do.	do.	1202	60	225	367	423	3.620	101.2	318.0	24.85	4	34	36	2.280	91.6	21.45	121.0	0.0184	
4	25	do.	do.	1203	60	225	378	439	4.080	92.6	372.0	24.85	4	34	36	2.195	88.3	19.98	119.0	0.0499	
6	60	do.	do.	1204	60	225	376	434	4.055	92.6	361.0	24.85	4	34	36	2.215	90.4	9.55	120.2	0.0493	
2	75	do.	do.	1205	60	225	313	375	3.170	98.8	308.0	24.85	4	34	36	2.000	82.5	20.18	98.6	0.0413	
4	75	do.	do.	1206	60	225	063	343	3.230	94.8	316.0	24.85	5	34	36	2.045	82.9	23.18	100.0	0.0404	
6	75	do.	do.	1207	60	225	315	359	3.100	101.5	312.0	24.85	4	34	36	1.985	79.0	14.46	104.9	0.0415	
8	75	do.	do.	1208	60	225	307	360	3.160	97.2	329.0	24.85	4	34	36	1.920	77.2	19.68	101.3	0.0405	
12	75	do.	do.	1209	60	225	318	358	3.575	89.0	370.0	24.85	4	34	36	1.930	77.6	16.00	94.6	0.0420	
12	25	do.	Stone dressed.	1211	60	225	280	318	3.445	81.3	302.0	26.50	6	30	90	2.280	86.0	9.89	139.0	0.00570	
8	25	do.	Same surface.	1212	60	207	280	348	3.390	82.6	302.0	26.50	7	30	90	2.244	84.8	12.10	139.5	0.0102	
6	25	do.	do.	1213	60	184	271	324	3.138	86.4	272.0	26.50	6	30	90	2.308	87.1	12.40	140.5	0.0436	
4	25	do.	do.	1214	60	179	274	334	3.360	81.5	290.0	26.50	7	30	90	2.165	87.5	11.63	140.0	0.0415	

Green wood was ground with bark on,

³ Green wood used.

Boiled in a 0.3 per cent soda-ash solution.

Seasoned wood used.

TABLE 6.—Grinder runs on spruce wood—cooked prior to grinding—Continued.

Grinder run No.	Cooking treatment.		Kind of burr.	Stone.		Number of pockets used.	Pressure on 14-inch cylinder	Revolutions per minute.	Average horsepower to grinder.	Maximum horsepower to grinder.	Bone-dry pulp in 24 hours.	Horsepower per ton bone-dry pulp in 24 hours.	Solid rossed wood ground in 24 hours.	Weight per cubic foot of wood (bone-dry).	Average diameter of wood.	Moisture in wood.	Pulp bone-dry per 100 cubic feet of solid rossed wood.	Efficiency of conversion.	Screenings bone-dry per 100 cubic feet solid rossed wood.	Average grinding temperature of ° F.	Horsepower divided by pressure X speed.
	Kind of cook.	Duration of cook.		Kind of burr.	Surface of stone.																
1 215	Steamed	Hrs. 2	Lbs. 25	Spiral, cut 8 to in.; straight, cut 10 to in.	Same surface.	2	Lbs. per sq. in. 60	174 274½	327	3 118	88.1	270.0	26.50	6½	30.90	2 310	87.1	14.16	136.4	0.00469	
1 216	do.	0	0	do.	do.	2	60	171 275	332	3 300	83.4	278.0	26.50	7	30.90	2 372	89.5	10.82	144.0	0.00477	
1 217	do.	12	75	do.	do.	2	60	225 320	361	3 300	97.0	357.0	26.50	7	30.90	1 848	69.6	12.06	136.4	0.0422	
1 218	do.	8	75	do.	do.	2	60	219 250	318	2 793	100.2	298.0	26.50	6	30.90	1 872	70.6	14.40	133.1	0.0380	
1 219	do.	6	75	do.	do.	2	60	214 274	327	2 192	125.0	334.0	26.50	8	30.90	1 873	70.7	11.43	140.7	0.0381	
1 220	do.	4	75	do.	do.	2	60	210 280	342	2 390	108.3	262.0	26.50	8	30.90	1 978	74.3	16.43	136.0	0.0396	
1 221	do.	2	75	do.	do.	2	60	217 280	367	2 390	117.0	220.0	26.50	7	30.90	2 170	81.9	12.10	140.0	0.0445	
1 222	do.	6	75	do.	Stone dressed	2	60	225 277	348	3 130	88.5	321.0	25.20	5½	34.69	1 952	77.5	18.90	131.0	0.0368	
1 223	do.	6	60	do.	Same surface.	2	60	207 281	345	3 150	89.2	285.0	25.20	5	34.69	2 205	87.5	27.00	131.0	0.0406	
1 224	do.	6	60	do.	do.	2	60	200 276	327	3 195	86.6	312.0	25.20	5	34.69	2 040	81.0	14.10	125.0	0.0413	
1 225	do.	6	20	do.	do.	2	60	179 277	338	3 845	72.0	332.0	25.20	5	34.69	2 315	91.8	17.50	137.0	0.0461	
1 226	do.	6	20	do.	do.	2	60	166 280	331	3 895	72.0	318.0	25.20	5	34.69	2 450	97.2	4.80	136.0	0.0537	
1 227	do.	0	0	do.	do.	2	60	216 277	332	3 055	90.7	294.0	25.20	4	34.69	2 150	85.4	19.30	133.0	0.0383	
1 228	do.	6	75	do.	do.	2	60	204 280	333	3 225	86.8	308.0	25.20	5	34.69	2 092	83.0	22.00	135.0	0.0410	
1 229	do.	6	60	do.	do.	2	60	179 278	328	3 355	82.9	300.0	25.20	5	34.69	2 238	88.7	15.10	136.0	0.0463	
1 230	do.	6	20	do.	do.	2	60	164 277	335	3 480	79.5	300.0	25.20	5	34.69	2 320	92.0	11.10	141.0	0.0504	
1 231	do.	6	20	do.	do.	2	60	157 278	328	3 980	69.9	328.0	25.20	5	34.69	2 425	96.4	9.90	133.0	0.0529	
1 232	do.	0	0	do.	do.	2	60	225 345	404	3 710	93.0	336.0	25.66	5	31.12	2 085	91.4	27.6	146.0	0.0458	
1 233	do.	9	75	Diamond point, cut 6 to in.	Stone dressed	2	60	225 345	415	3 540	98.3	334.0	25.66	5	31.12	2 120	82.6	20.4	138.0	0.0495	
1 234	do.	9	60	do.	Same surface.	2	60	210 348	415	3 540	98.3	334.0	25.66	5	31.12	2 120	82.6	20.4	138.0	0.0495	
1 235	do.	6	40	do.	do.	2	60	206 344	390	3 510	98.0	323.0	25.66	5	31.12	2 176	84.7	17.5	140.0	0.0500	
1 236	do.	6	20	do.	do.	2	60	187 344	409	4 150	82.9	364.0	25.66	5	31.12	2 580	88.9	25.2	141.0	0.0550	
1 237	do.	6	0	do.	do.	2	60	178 339	385	4 090	83.0	343.0	25.66	5	31.12	2 385	93.0	12.0	142.0	0.0370	
1 238	do.	3	75	do.	do.	2	60	205 347	398	3 710	92.5	362.0	25.66	5	31.12	2 048	79.9	20.6	142.0	0.0506	
1 239	do.	3	60	do.	do.	2	60	192 344	408	4 050	85.0	376.0	25.66	5	31.12	2 153	83.0	27.3	137.0	0.0385	
1 240	do.	3	40	do.	do.	2	60	191 342	388	4 150	82.5	365.0	25.66	4	31.12	2 278	88.6	21.9	134.0	0.0535	
1 241	do.	3	20	do.	do.	2	60	188 347	390	4 300	80.7	360.0	25.66	6	31.12	2 395	93.2	29.0	138.0	0.0552	
1 242	do.	0	0	do.	do.	2	60	176 354	398	4 360	81.2	378.0	25.66	4	31.12	2 310	90.0	15.0	129.0	0.0501	

12 235	do	8	60	Straight, cut 3 to in. spiral, cut 12 to in.	Stone dressed	2	60	225 334	376	5.735	58.3	641.0	24.36	42	28.73	1.788	73.413.0	129.0	.00434
1266	do	6	60	do	Same surface	2	60	217 336	402	5.875	57.3	630.0	24.36	43	28.73	1.867	76.6119.7	125.0	.00452
1267	do	6	60	do	do	2	60	202 336	373	5.840	57.6	622.0	24.36	44	28.73	1.878	77.1151.3	125.0	.00456
1268	do	4	60	do	do	2	60	191 328	373	6.615	49.6	601.0	24.36	45	28.73	2.200	90.4 53.3	126.0	.00502
1269	do	2	60	do	do	2	60	181 339	409	6.910	49.0	605.0	24.36	46	28.73	2.280	93.6 55.0	130.0	.00548
1270	do	0	60	do	do	2	60	200 261	319	4.050	64.5	421.0	25.11	5	28.88	1.920	76.5118.2	129.0	.00573
1271	do	6	60	do	do	2	60	200 320	374	5.645	56.8	579.0	25.11	51	28.88	1.950	77.7143.8	113.0	.00468
1272	do	6	60	do	do	2	80	200 379	430	6.500	58.3	685.0	25.11	5	28.88	1.900	75.7212.0	126.0	.00417
1273	do	6	40	do	do	2	60	189 320	362	5.600	57.4	563.0	25.11	43	28.88	1.990	79.4244.0	126.0	.00495
1274	do	6	20	do	do	2	60	171 326	357	5.910	55.1	533.0	25.11	5	28.88	2.220	88.4183.0	110.0	.00553
1275	do	0	0	do	do	2	60	168 324	357	6.110	53.0	534.0	25.11	53	28.88	2.285	91.1 39.2	119.0	.00564

² Runs 265 to 275, inclusive, were ground on a coarse grit stone.

¹ Seasoned wood used.

TABLE 7.—*Quality tests—white spruce.*

Grinder run No.	Paper machine run No.	Ground wood in total furnish.	Weight per ream.	Mullen test.				Schopper tests.						Tintometer indications.			
				Total.	Per 0.001 inch of thickness.	Per pound.	Horsepower per ton divided by strength factor.	Breaking length.			Stretch.			Red.	Green.	Blue.	Black.
				Points.	Points.	Points.	Points.	Crosswise.	Lengthwise.	Average.	Per ct.	Lengthwise.	Average.	Per ct.	Parts.	Parts.	Parts.
1	110	80	32.0	12.15	3.14	0.380	256.0	2.600	4.000	3,300	3.00	1.40	2.20	95	86	78	41
2	62	80	32.0	16.4	4.55	.513	306.0	3.075	5,300	4,188	2.04	1.22	1.63	89	80	73	58
3	75	80	37.0	19.35	4.72	.523	210.0	3.585	6,040	4,821	1.98	1.04	1.51	87	76	66	71
4	40	80	29.0	11.3	2.97	.390	221.0	2,420	5,640	3,530	1.74	.98	1.36	89	78	68	65
5	42	80	40.0	.0047	2.1	.4	351.0	2,500	5,440	3,970	1.18	1.10	1.14	90	80	70	60
6	11	80	40.0	.0047	2.1	.4	351.0	2,500	5,440	3,970	1.18	1.10	1.14	88	79	69	64
7	22	79	33.0	15.7	4.13	.476	229.0	3,120	6,210	4,665	1.76	1.06	1.41	88	77	64	72
8	56	80	34.0	.0043	3.27	.413	221.0	2,673	4,780	3,727	1.66	1.10	1.38	87	77	69	64
9	51	80	33.0	.00384	4.72	.544	323.0	3,344	5,610	4,517	2.86	1.58	2.22	92	82	71	86
9-1	16	80	35.0	.0046	3.74	.493	189.0	3,040	4,225	3,158	1.58	.98	1.22	96	79	75	50
10	72	80	33.0	.00394	3.60	.429	174.0	2,973	5,358	4,166	1.40	1.04	1.22	91	78	70	61
11	45	80	34.0	.0042	2.94	.363	180.0	2,123	4,335	3,269	1.92	1.30	1.21	97	85	76	42
12	92	80	34.0	.0047	3.75	.460	163.0	3,180	5,820	4,250	1.78	1.10	1.54	90	79	66	65
13	20	80	34.0	.0040	3.25	.382	176.0	2,655	5,030	3,843	1.98	1.12	1.53	90	79	69	62
14	28	80	32.0	.0047	2.77	.382	170.0	2,065	4,325	3,195	1.94	1.12	1.53	90	80	74	56
15	15	80	32.0	.00414	2.77	.358	181.0	2,228	4,020	3,124	1.74	1.10	1.66	84	72	66	78
16	19	80	30.0	.0043	4.06	.552	231.0	3,865	5,750	4,509	2.22	1.10	1.71	85	75	64	78
17	48	80	33.0	.00298	4.47	.406	196.0	2,335	5,960	4,529	2.16	1.26	1.71	88	78	73	74
18	73	80	33.0	.0033	4.40	.450	196.0	2,335	5,960	4,529	2.16	1.26	1.71	86	77	70	67
19	20	80	35.0	.00397	3.56	.467	192.0	2,335	5,960	4,529	2.16	1.26	1.71	95	82	73	48
20	43	80	31.0	.0039	5.69	.532	240.0	3,384	6,880	5,032	2.66	1.48	2.02	87	78	67	88
21	21	80	34.0	.0045	25.6	.468	183.0	2,335	5,960	4,529	2.16	1.26	1.71	82	73	61	83
22	77	80	33.0	.00355	18.75	.520	273.0	3,400	5,930	4,625	2.62	1.24	1.63	82	75	70	71
23	67	80	33.0	.00355	18.75	.520	273.0	3,400	5,930	4,625	2.62	1.24	1.63	86	74	67	73
24	59	80	31.0	.00373	15.9	.430	196.0	3,105	5,430	4,248	2.18	1.18	1.68	88	78	68	88
25	50	80	36.0	.0041	4.36	.487	178.0	3,045	5,630	4,325	2.60	1.60	2.10	88	75	64	78
26	8	80	33.0	.0042	13.85	.420	194.0	2,445	5,018	3,732	1.24	1.08	1.15	88	73	66	78
27	86	80	32.0	.0039	16.1	.467	229.0	2,965	5,200	3,833	2.04	1.08	1.54	95	79	71	55
28	95	80	32.0	.00365	18.2	.441	240.0	3,570	5,430	4,525	2.04	1.12	1.58	88	79	71	62
29-1	64	80	31.0	.0036	15.15	.489	201.0	3,195	5,020	4,108	2.22	1.14	1.68	85	76	68	71

68	67	78	87	91	47.0	1.914	1.63	1.14	2.12	4.348	5.400	3.295	191.0	.484	4.17	15.00	.00364	31.0	80
57	72	80	91	91	42.5	1.928	1.40	1.08	1.72	4.235	5.430	3.000	234.0	.427	3.79	13.25	.0035	31.0	80
64	71	78	87	87	46.2	1.220	1.03	.94	1.12	2.915	3.745	2.085	220.0	.274	2.07	8.5	.0041	31.0	80
67	77	77	87	87	56.2	1.254	1.12	.88	1.12	3.205	4.230	2.180	188.0	.303	2.22	10.0	.0034	31.0	80
68	76	76	80	80	50.6	1.260	1.04	.88	1.20	3.070	4.000	2.140	186.0	.326	2.29	10.75	.0047	33.0	80
84	66	72	93	93	53.1	1.365	1.22	.96	1.48	3.441	4.600	2.282	183.5	.354	2.66	11.7	.0044	33.0	80
61	61	79	90	90	55.8	1.500	1.24	1.00	1.48	3.615	4.935	2.204	181.0	.358	2.73	11.45	.0041	33.0	80
74	66	74	86	86	53.5	1.414	1.18	1.12	1.48	3.360	4.060	2.070	174.0	.363	2.87	12.35	.0043	34.0	80
64	76	76	83	83	51.7	1.340	1.52	1.08	1.96	3.265	3.970	2.500	172.0	.363	2.83	12.65	.00436	34.0	80
86	61	70	88	88	44.0	1.236	1.43	1.08	1.78	3.950	3.570	2.330	197.0	.341	2.64	12.30	.0044	34.0	80
72	65	81	83	83	49.5	1.570	1.01	.98	1.78	3.613	4.725	2.500	221.0	.331	2.74	9.95	.00363	30.0	80
87	62	74	89	89	48.5	1.615	1.21	.98	1.44	3.693	4.635	2.750	202.0	.330	3.14	13.80	.0044	30.0	80
72	65	74	84	84	48.22	1.610	1.27	1.08	1.46	3.878	4.950	2.805	189.0	.403	3.10	12.10	.0039	30.0	80
82	61	76	87	87	39.8	2.014	1.63	1.12	2.14	3.026	5.280	2.773	229.0	.442	3.91	13.70	.0035	30.0	80
65	72	76	84	84	39.6	1.910	1.73	1.32	1.40	3.010	5.210	2.810	235.0	.431	3.73	13.8	.0037	30.0	80
80	70	80	88	88	45.5	1.695	1.20	1.00	1.40	3.910	5.170	2.650	224.0	.384	3.30	11.9	.0036	31.0	80
63	61	72	84	84	45.5	1.695	1.20	1.00	1.40	3.910	5.170	2.650	224.0	.384	3.30	11.9	.0036	31.0	80
93	59	69	70	70	40.7	2.010	2.04	1.22	2.72	3.003	5.135	3.055	197.0	.455	4.31	15.95	.0037	35.0	80
61	79	79	87	87	40.7	1.710	1.88	1.22	2.54	3.888	5.280	3.280	188.0	.482	3.80	14.45	.0038	30.0	80
72	66	75	87	87	44.0	1.545	2.04	1.54	2.54	3.517	5.020	2.714	188.0	.425	3.40	13.6	.0040	32.0	80
89	70	73	80	80	33.8	2.300	1.71	1.28	2.02	4.435	5.415	3.455	288.0	.456	4.05	14.6	.0036	32.0	80
75	68	79	86	86	44.0	1.940	1.39	1.06	1.72	4.147	5.280	3.014	246.0	.411	4.11	14.8	.00356	32.0	80
166	66	66	86	86	42.6	2.355	1.92	1.16	1.92	4.095	5.300	3.490	210.0	.444	3.68	14.7	.0040	33.0	80
73	76	76	83	83	42.0	2.880	1.38	1.38	2.68	4.400	5.400	3.460	183.0	.569	5.55	20.5	.0037	36.0	80
63	68	73	83	83	38.6	2.880	1.49	1.14	1.92	4.165	5.805	3.525	366.0	.495	5.88	17.35	.00295	35.0	80
69	69	79	89	89	55.5	1.810	1.49	1.14	1.84	4.040	5.155	2.925	270.0	.388	3.35	11.25	.00336	35.0	80
75	75	73	83	83	55.5	1.728	1.50	1.16	1.84	3.783	4.580	2.985	180.0	.380	3.14	13.30	.00423	35.0	80
63	71	73	83	83	56.2	1.395	1.26	1.02	1.50	3.353	4.260	2.445	195.0	.306	2.28	8.9	.0039	35.0	80
74	66	74	86	86	55.8	1.394	1.05	.92	1.18	3.180	4.060	2.300	175.0	.326	2.48	10.5	.0041	31.0	80
63	63	74	82	82	43.3	1.934	1.72	1.18	2.26	4.298	5.350	3.245	211.0	.470	4.01	16.45	.0048	35.0	80
87	68	75	82	82	57.2	1.517	1.22	1.00	1.44	3.550	4.385	2.715	173.0	.358	2.74	11.45	.00417	35.0	80
70	68	75	87	87	45.1	2.000	1.51	1.20	1.82	4.150	5.190	3.110	199.5	.461	3.85	13.85	.0036	30.0	80
56	74	81	91	91	43.3	1.953	1.78	1.36	2.50	4.050	5.000	3.110	189.5	.483	4.25	15.95	.00375	33.0	80
62	74	79	91	91	45.5	1.775	1.61	1.18	2.04	3.933	5.040	3.040	210.0	.413	3.38	12.05	.00416	34.0	80
72	67	78	85	85	48.6	1.712	1.31	1.10	1.52	3.975	5.040	2.910	215.0	.380	3.04	12.15	.0040	32.0	80
67	76	76	88	88	47.0	1.640	1.31	1.02	1.60	3.697	4.635	2.760	191.0	.412	3.28	11.95	.00365	29.0	80
69	76	76	87	87	45.1	1.569	1.32	1.01	1.63	3.697	4.635	2.445	233.0	.345	2.85	11.40	.0040	33.0	80
82	62	72	84	84	45.5	1.640	1.35	1.02	2.00	3.773	4.635	2.910	194.5	.426	3.31	14.05	.00425	33.0	80
73	66	76	86	86	42.8	1.395	1.19	1.02	1.35	3.187	4.218	2.155	211.0	.353	2.35	12.35	.00352	35.0	80
70	62	79	89	89	46.4	1.610	1.39	1.06	1.72	3.795	4.840	2.750	188.5	.434	3.14	14.75	.0047	34.0	80
62	70	83	92	92	48.8	1.510	1.27	.96	1.58	3.467	4.505	2.485	171.5	.400	2.98	12.8	.0043	32.0	80
52	73	83	94	94	50.8	1.203	1.11	1.03	1.26	3.074	4.095	2.053	209.0	.288	2.18	9.2	.0042	32.0	80
84	76	76	84	84	50.8	1.310	1.31	.98	1.64	3.088	4.206	2.045	185.5	.328	2.18	11.15	.0046	34.0	80
66	74	74	84	84	30.9	2.368	1.63	1.18	2.08	4.128	5.206	3.050	271.0	.4946	5.169	18.30	.00354	30.0	80
199	39	45	46	46	31.7	1.940	1.84	1.26	2.42	3.890	3.780	2.780	218.0	.576	4.150	19.00	.00458	37.0	80
117	54	54	68	68	31.7	1.421	1.55	1.10	2.00	2.845	3.705	2.985	283.0	.310	2.750	10.15	.00369	33.0	80
115	66	66	83	83	24.1	1.982	1.80	1.30	2.30	3.875	4.852	2.895	258.0	.4415	4.01	15.00	.00374	34.0	80
56	55	55	67	67	22.8	1.982	1.75	1.36	2.14	3.875	4.852	2.895	258.0	.4415	4.01	15.00	.00374	34.0	80
136	27	32	45	45	19.4	3.240	2.05	1.54	2.56	4.265	5.430	3.100	440.0	.500	5.030	17.25	.00348	35.0	80
135	38	44	63	63	31.8	2.425	1.77	1.20	2.34	4.416	5.424	3.408	251.0	.5532	5.350	19.90	.00372	36.0	80

TABLE 7.—Quality tests—white spruce—Continued.

Grinder run No.	Paper machine run No.	Ground wood in total furnish.	Weight per ream.	Thickness.	Mullen test.				Schopper tests.						Tintometer indications.					
					Total.	Per 0.001 inch of thickness.	Per pound.	Horsepower per ton divided by strength factor.	Breaking length.			Stretch.			Breaking weight per square millimeter, sectional area.	Breaking length per ton.	Red.	Green.	Blue.	Black.
									Meters.	Lengthwise.	Average.	Per ct.	Crosswise.	Lengthwise.							Average.	Per ct.	Grams.	Meters.
79	192	80	33.0	0.00349	17.70	5.070	0.5364	237.0	3.520	6.744	5.132	1.84	1.08	1.46	2,801	40.3	53	34	27	186
80	190	80	31.0	0.00326	15.85	4.86	0.5112	559.0	3.688	7.460	5.574	1.80	1.18	1.40	3,002	19.5	76	70	64	90
81	191	80	31.0	0.00351	13.90	3.96	0.4484	295.0	3.459	6.631	5.045	1.94	1.06	1.50	4,489	38.1	97	85	70	48
82	172	80	35.0	0.00408	14.00	3.43	0.405	242.0	2.475	4.100	3.283	2.34	1.32	1.83	1,580	33.6	67	55	48	130
83	184	80	31.0	0.00367	11.70	3.19	0.3775	261.0	2.995	5.100	4.047	1.72	1.04	1.38	1,891	41.0	75	67	61	97
84	183	80	34.0	0.00414	15.54	3.73	0.4545	238.0	3.840	5.270	4.055	1.74	1.10	1.42	1,893	34.6	62	65	62	95
85	169	80	35.0	0.00429	14.20	3.312	0.4080	223.0	3.176	4.826	4.001	1.90	1.04	1.47	1,958	43.1	87	76	69	68
86	178	80	34.0	0.00418	14.10	3.37	0.4100	216.0	3.890	4.850	3.870	1.72	.98	1.35	1,725	43.7	75	65	60	100
87	179	80	34.0	0.00399	15.50	3.89	0.4565	265.0	3.095	5.685	4.390	1.78	1.16	1.43	2,140	36.2	86	78	71	71
88	163	80	30.0	0.00367	11.80	3.217	0.3935	290.0	3.830	4.680	3.759	2.06	1.22	1.64	1,748	32.9	84	74	71	71
89	180	80	35.0	0.00400	14.25	3.56	0.4070	281.0	3.893	4.610	3.746	1.82	1.18	1.50	1,803	32.8	92	81	73	54
90	181	80	32.0	0.00394	10.65	2.70	0.3200	298.0	2.578	4.200	3.519	1.44	.82	1.18	1,637	41.0	85	72	68	75
91	182	80	32.0	0.00417	11.25	2.70	0.3517	294.0	2.700	4.228	3.464	1.54	.82	1.18	1,508	44.1	87	78	69	66
92	198	80	30.0	0.00361	12.35	3.42	0.4117	283.0	2.862	5.722	4.292	1.53	1.04	1.31	1,743	36.9	80	71	63	81
(C)																				
97	145	80	34.0	0.00363	19.20	5.292	0.5650	150.0	2.890	6.012	4.451	2.49	1.00	1.74	2,293	52.5	61	41	32	166
98	146	80	34.0	0.00349	17.30	4.957	0.5088	134.0	2.832	5.694	4.263	2.56	1.33	1.95	2,238	62.6	54	35	29	182
99	193	80	30.0	0.00318	13.15	4.135	0.4385	175.0	2.891	6.287	4.584	1.88	1.02	1.45	2,421	59.7	65	43	35	157
100	165	80	33.0	0.00347	16.25	4.684	0.4926	161.0	2.715	5.345	4.030	2.50	1.32	1.45	2,117	51.0	54	37	30	179
101	196	80	31.0	0.00337	15.20	4.51	0.4905	185.0	2.630	5.538	4.034	1.98	1.14	1.56	2,072	48.5	56	38	31	176
102	101	80	33.0	0.00338	16.15	4.780	0.4895	186.0	3.114	5.732	4.323	1.80	.96	1.58	2,350	48.5	43	30	22	205
103	158	80	33.0	0.00417	12.40	2.974	0.3757	211.0	2.863	5.107	4.235	1.94	1.20	1.57	2,801	50.3	73	64	57	101
104	159	80	34.0	0.00350	16.50	4.715	0.4851	193.0	3.392	5.760	4.576	2.20	1.28	1.92	2,137	58.3	76	64	57	103
105	159	80	32.0	0.00386	16.50	4.280	0.5160	188.0	3.575	5.945	4.760	1.76	.92	1.34	2,339	53.7	74	59	50	121
106	185	80	30.0	0.00353	14.85	4.21	0.495	180.0	2.901	5.891	4.396	2.16	1.00	1.59	2,060	49.4	72	58	44	121
107	194	80	33.2	0.00375	17.55	4.68	0.529	171.0	3.395	5.328	4.860	2.20	.98	1.59	2,455	53.6	68	53	44	135
108	136	80	31.0	0.00386	13.95	3.616	0.4536	196.0	3.045	5.460	4.254	2.32	1.18	1.75	1,942	47.8	78	62	53	107
109	159	80	33.0	0.00375	17.35	4.630	0.5258	157.5	3.155	5.900	4.528	2.42	1.24	1.86	2,203	54.6	65	48	41	146
110	139	80	34.0	0.00375	21.30	5.703	0.6266	156.0	3.240	6.176	4.088	2.30	1.32	1.81	2,473	48.1	59	44	36	163
111	138	80	34.0	0.003645	20.45	5.612	0.6015	150.8	3.343	6.920	4.970	2.38	1.26	1.82	2,590	54.9	54	38	30	178
112	144	80	32.0	0.0032	18.50	5.78	0.5781	157.0	3.270	6.100	4.085	2.18	1.22	1.70	2,490	51.6	57	40	30	173
113	141	80	30.0	0.00393	11.50	2.928	0.3834	197.0	2.731	4.711	3.721	1.62	.93	1.30	1,530	49.3	88	74	67	71

113.....	148	80	22.0	0.00328	18.15	5.536	5674	170.0	2,860	4,870	3,965	2,42	1.36	1.89	2,130	40.0	54	34	27	185
114.....	149	80	31.0	0.00392	10.25	2.578	3207	223.0	2,362	4,066	3,214	2.74	1.08	1.61	1,430	43.5	83	76	65	74
115.....	151	80	33.0	0.00398	13.00	2.518	4241	213.0	3,074	5,810	4,292	2.12	1.04	1.53	1,850	47.5	71	53	47	129
116.....	150	80	31.0	0.00391	17.15	5.060	5500	185.0	2,773	5,995	4,324	2.83	1.12	1.83	2,256	42.5	63	48	41	148
117.....	155	80	31.0	0.00337	16.95	5.060	5470	193.0	2,902	5,985	4,448	1.86	1.00	1.45	2,379	41.7	51	33	25	191
118.....	156	80	32.0	0.00337	14.30	4.280	4470	228.0	2,826	5,010	3,918	2.84	1.04	1.94	2,122	38.4	51	32	27	190
119.....	158	80	32.0	0.00323	14.15	4.380	4430	223.0	2,768	4,748	3,758	3.12	1.02	2.07	2,122	38.0	42	26	20	212
120.....	153	80	31.0	0.00422	8.35	1.979	2694	216.0	2,572	3,910	3,241	1.74	.92	1.33	1,315	55.6	80	70	61	89
121.....	152	80	33.0	0.00429	12.20	2.843	3698	178.0	2,870	4,722	3,796	1.44	1.00	1.22	1,731	57.7	85	74	67	74
122.....	157	80	34.0	0.00408	14.25	3.50	419	212.0	2,580	4,565	3,568	2.44	1.20	1.42	1,590	40.1	65	56	52	127
123.....	153	80	34.0	0.00416	12.65	3.040	3720	234.0	3,064	4,442	3,753	1.88	1.06	1.47	1,748	43.1	89	78	74	59
124.....	157	80	32.0	0.00386	12.45	3.225	3890	204.0	2,716	4,765	3,740	1.74	1.20	1.47	1,701	47.0	88	82	72	58
125.....	141	80	31.0	0.00365	14.35	3.932	4630	207.0	3,288	5,460	4,374	2.22	1.36	1.79	2,080	45.8	93	82	76	49
126.....	131	80	32.0	0.00351	15.35	4.369	4796	284.0	3,172	5,185	4,178	2.96	1.38	2.17	2,078	30.7	91	81	73	55
127.....	133	80	33.0	0.0043	13.775	3.204	4175	196.0	2,574	4,212	3,393	2.68	1.00	1.40	1,672	41.5	89	75	69	67
128.....	188	80	32.0	0.00373	15.10	4.05	4660	199.0	3,257	5,585	4,071	1.84	.96	1.90	2,101	47.5	88	72	68	72
129.....	154	80	31.0	0.00334	16.40	4.910	5290	288.0	3,810	6,348	5,029	2.58	1.33	1.40	2,448	33.3	79	69	57	95
130.....	130	80	34.0	0.00352	19.40	5.514	5709	169.5	3,152	6,072	4,612	2.93	1.14	1.76	2,334	47.6	61	39	31	169
131.....	124	80	30.0	0.0031	19.90	6.41	663	150.0	2,684	5,350	4,017	2.90	1.36	1.61	2,195	40.5	77	57	49	117
132.....	132	80	33.0	0.00332	22.3	6.72	675	173.0	2,765	5,552	4,214	2.36	1.42	1.89	2,224	36.2	63	46	39	152
133.....	126	80	34.0	0.00405	15.1	3.73	444	196.0	2,958	4,662	3,810	2.26	1.38	1.82	1,815	43.8	94	83	74	49
134.....	180	80	31.0	0.00379	11.90	3.14	3839	255.0	3,152	5,712	4,432	1.68	1.06	1.37	2,068	45.3	83	72	66	79
135.....	140	80	30.0	0.003755	10.55	2.810	3518	199.0	2,700	4,591	3,645	1.58	1.00	1.29	1,596	52.3	89	79	69	63
136.....	129	80	34.0	0.00455	13.35	2.93	3928	183.0	2,466	3,958	3,212	2.92	1.06	1.37	2,068	45.3	83	72	66	79
137.....	127	80	32.0	0.00378	16.82	4.46	5267	214.0	3,600	6,004	4,802	1.96	1.12	2.05	1,437	41.5	87	74	68	71
138.....	121	80	31.0	0.00359	15.25	4.25	492	200.0	3,255	4,920	4,088	2.98	1.34	2.16	1,526	37.4	84	73	67	71
139.....	123	80	33.0	0.00429	18.95	4.15	534	155.0	2,652	4,776	3,980	2.40	1.12	2.05	1,830	48.6	87	76	69	68
140.....	143	80	31.0	0.00356	15.00	3.77	4766	263.0	3,810	5,840	4,825	2.40	1.36	2.16	2,253	38.0	87	76	69	68
141.....	130	80	32.0	0.0042	11.80	2.809	3689	194.0	2,740	4,990	3,665	2.98	1.40	2.19	1,756	39.6	80	72	67	81
142.....	122	80	33.0	0.00426	14.8	3.47	448	186.0	2,805	4,380	3,593	2.34	1.30	1.87	1,495	39.9	89	78	72	61
143.....	118	80	31.0	0.00414	14.05	3.54	4725	178.0	2,712	4,350	3,551	2.44	1.40	1.92	1,608	43.1	86	68	68	70
144.....	128	80	33.0	0.004185	13.175	3.149	3993	196.0	2,831	4,981	3,906	1.90	1.10	1.50	1,605	49.4	88	79	76	65
145.....	168	80	31.0	0.00375	12.10	3.228	3892	248.0	3,086	4,716	3,901	1.60	1.04	1.32	1,805	40.5	83	70	64	83
146.....	147	80	35.0	0.00407	14.65	3.599	4187	210.0	3,266	4,680	3,973	2.84	1.22	2.03	1,917	45.0	85	76	68	71
147.....	160	80	32.0	0.00405	12.50	3.087	3906	220.0	2,728	4,860	3,794	2.14	1.26	2.03	1,846	44.2	83	72	65	80
148.....	164	80	33.0	0.00350	11.00	3.140	3375	302.0	2,658	4,628	3,643	2.58	1.36	1.97	1,730	38.9	86	56	50	128
149.....	174	80	32.0	0.00398	12.35	3.104	3859	254.0	3,064	4,554	3,809	2.20	1.10	1.65	1,848	35.9	80	69	64	87
150.....	161	80	34.0	0.00418	14.70	3.518	4326	217.0	3,162	4,818	3,990	2.40	1.16	1.78	1,944	42.5	84	72	68	76
151.....	152	80	30.4	0.00355	15.10	4.25	4965	345.0	3,701	6,259	4,830	1.66	1.04	1.35	2,305	28.2	89	77	73	61
152.....	197	80	34.0	0.0044	15.0	3.4	44	228.0	2,680	4,480	3,580	2.12	1.00	1.56	1,570	35.6	72	62	56	110
153.....	405	80	34.0	0.0035	17.9	5.1	51	393.0	3,280	6,050	4,660	2.66	1.58	2.12	2,310	23.2	77	66	58	99
154.....	374	83	35.0	0.0043	15.4	4.0	43	486.0	3,070	5,960	4,520	2.08	1.44	1.76	2,160	21.6	75	63	54	108
155.....	355	80	36.0	0.0038	15.4	4.0	43	486.0	3,130	5,960	4,300	2.12	1.18	1.55	2,060	32.5	80	68	60	92
156.....	357	80	34.0	0.0038	13.7	3.6	40	332.0	3,100	5,500	4,300	2.10	1.22	1.68	1,880	37.8	80	61	53	115
157.....	357	80	33.0	0.0038	12.9	3.4	39	292.0	3,100	5,500	4,300	2.10	1.22	1.68	1,880	37.8	80	61	53	115
158.....	358	80	32.0	0.0028	14.2	5.1	44	267.0	2,740	4,570	3,660	2.02	1.34	1.66	2,350	31.8	71	61	62	97
159.....	244	80	31.0	0.0032	16.4	5.2	53	258.0	3,420	5,250	4,340	2.76	1.28	2.02	2,360	31.8	72	64	60	104
160.....	243	80	31.0	0.0032	16.4	5.2	53	258.0	3,420	5,250	4,340	2.76	1.28	2.02	2,360	31.8	72	64	60	104
161.....	245	80	32.0	0.0033	17.6	5.4	56	265.0	3,360	5,720	4,540	2.72	1.52	2.12	2,240	30.6	77	69	63	91

192 to 96, inclusive, qualitative grinder runs; no production data.

TABLE 7.—Quality tests—white spruce—Continued.

Grinder run No.	Paper machine run No.	Ground wood in total furnish.	Weight per ream.	Mullen test.			Schopper tests.						Tintometer indications.					
				Total.	Per 0.001 inch of thickness.	Per pound.	Horsepower per ton divided by strength factor.	Breaking length.			Stretch.		Breaking weight per square millimeter, sectional area.	Breaking length per ton.	Red.	Green.	Blue.	Black.
								Crosswise.	Lengthwise.	Average.	Crosswise.	Lengthwise.							Average.
62.	247	80	30.0	16.2	5.3	0.55	238.0	3,270	5,340	4,300	2.46	1.40	1.93	32.9	75	66	61	98
63.	248	80	37.0	20.4	5.5	.55	218.0	3,520	5,640	4,580	2.54	1.24	1.89	33.2	78	71	64	87
64.	249	80	31.0	16.8	4.8	.45	294.0	2,980	5,740	4,360	1.92	1.26	1.59	38.0	77	67	60	96
65.	250	80	31.0	16.8	4.8	.45	253.0	3,260	6,090	4,680	1.98	1.26	1.62	34.2	72	62	55	111
66.	251	80	28.0	14.8	4.8	.53	220.0	3,130	5,760	4,440	2.46	1.35	1.92	38.1	72	65	59	104
67.	252	100	36.6	21.15	7.24	.578	566.0	3,575	7,199	5,387	1.98	1.02	1.50	37.49	44	26	20	210
68.	253	100	38.4	22.7	6.90	.591	269.0	3,340	5,750	4,545	1.78	.84	1.31	38.0	42	26	18	214
69.	254	100	36.4	22.7	6.90	.591	174.0	2,871	6,325	4,998	1.58	1.00	1.39	38.044	39	23	18	220
70.	255	100	37.0	23.4	7.73	.643	175.0	3,679	6,209	4,944	1.58	.90	1.24	41.1	39	22	17	221
71.	256	100	35.0	13.7	4.80	.3915	321.0	3,366	6,345	4,934	1.40	.86	1.16	39.2	40	22	17	221
72.	257	100	41.0	20.5	6.53	.500	382.0	3,623	6,345	4,984	1.42	.90	1.16	35.50	33	19	13	235
73.	258	100	43.0	22.8	6.56	.530	229.0	3,600	7,140	5,370	1.86	1.02	1.42	36.30	35	23	14	233
74.	259	100	33.6	18.15	6.45	.5401	204.0	3,324	6,972	5,148	1.46	.98	1.22	32.325	41	23	17	219
75.	260	100	35.0	21.3	7.35	.609	181.0	3,546	6,405	5,020	1.80	.90	1.35	38.310	42	24	17	217
76.	261	100	39.4	26.65	8.25	.6765	168.0	3,620	6,255	4,938	2.98	1.08	2.03	38.260	46	30	23	201
77.	262	80	31.0	17.9	5.6	.57	363.0	3,380	6,560	4,980	2.00	1.24	1.62	34.0	75	65	60	100
78.	263	80	34.0	20.3	4.6	.51	245.0	3,080	5,440	4,260	2.12	1.26	1.69	34.1	81	74	68	77
79.	264	80	32.0	15.9	4.4	.50	189.0	3,080	5,600	4,340	2.00	1.26	1.63	51.9	78	68	60	100
80.	265	80	37.0	19.2	3.1	.38	182.0	3,280	5,800	4,340	2.18	1.08	1.74	46.4	81	66	60	100
81.	266	100	35.0	27.0	7.95	.63	199.0	3,630	4,370	3,500	1.72	1.08	1.40	37.3	41	25	20	216
82.	267	100	43.0	25.0	8.12	.7215	226.0	3,880	6,740	5,310	3.04	1.08	2.06	37.3	41	25	20	216
83.	268	100	38.0	25.25	8.0	.72	140.0	3,105	6,523	4,814	1.92	1.22	1.57	47.7	47	47	20	204
84.	269	100	42.0	27.8	8.0	.72	132.0	3,450	5,780	4,620	3.08	1.42	2.05	45.2	46	29	21	204
85.	270	100	48.0	24.4	6.9	.64	130.0	3,150	6,130	4,640	2.68	1.98	2.53	55.5	48	32	24	196
86.	271	100	44.0	32.8	7.45	.68	119.0	3,220	6,190	4,700	3.68	1.38	2.38	57.9	46	29	21	204
87.	272	100	48.0	33.2	7.3	.64	134.0	2,940	5,120	4,030	2.64	1.34	1.99	46.8	42	26	21	204
88.	273	100	47.0	37.4	8.7	.76	146.0	3,980	6,670	4,820	2.54	1.42	1.98	47.1	44	27	20	209
89.	274	100	53.0	36.6	8.0	.69	123.0	3,660	6,680	5,340	2.66	1.10	1.88	60.3	45	27	19	209
90.	275	100	44.0	28.0	7.8	.64	115.0	3,510	6,370	4,940	2.94	1.06	1.88	34.10	43	26	17	214
91.	276	100	49.0	26.8	6.5	.55	234.0	3,510	6,280	4,940	2.62	1.34	1.98	36.0	41	24	17	218
92.	277	100	37.0	20.0	6.6	.54	251.0	3,020	6,760	4,890	2.44	1.54	1.99	32.4	41	24	17	218

194	293	106	44.0	.0036	27.6	7.7	.63	3.150	6.270	4.720	3.50	1.92	2.71	3.250	28.2	42	25	18	215
195	266	100	41.0	.0033	23.8	7.2	.58	3.580	6.530	5.100	2.04	1.32	1.68	3.370	28.3	50	33	25	192
196	267	100	39.0	.0031	21.0	6.8	.54	3.910	6.550	5.000	2.14	1.32	1.73	3.350	28.8	44	27	19	210
197	385	100	40.0	.0034	26.6	7.8	.66	280.0	7.130	5.770	2.04	1.06	1.55	3.760	21.3	59	41	31	166
198	375	100	35.0	.0036	17.3	4.8	.49	372.0	6.080	4.670	2.42	1.72	2.07	2.230	25.6	75	66	57	102
199	318	100	38.0	.0035	20.8	5.9	.54	185.0	6.790	4.810	1.68	1.62	1.65	2.860	48.3	55	38	27	180
200	311	100	35.0	.0037	17.3	4.8	.49	372.0	6.730	4.970	2.24	1.38	1.81	3.160	40.4	59	50	33	138
201	317	100	42.0	.0042	21.6	5.0	.51	199.0	5.610	4.100	1.38	1.38	1.38	2.200	40.4	69	55	45	131
202	315	100	40.0	.0043	19.7	4.7	.50	197.0	4.880	3.990	1.98	1.32	1.66	2.150	39.4	72	61	52	115
203	316	100	36.0	.0039	16.8	4.3	.47	202.0	5.120	4.230	1.98	1.32	1.66	2.040	45.6	61	49	42	148
204	336	80	38.0	.0043	15.7	3.6	.41	226.0	4.780	3.900	2.24	1.32	1.59	1.850	42.1	82	71	64	83
205	309	100	38.0	.0035	15.8	5.6	.52	190.0	6.380	4.700	1.76	1.42	1.59	2.780	47.6	66	46	37	151
206	307	100	38.0	.0033	19.0	5.8	.50	190.0	6.140	4.180	1.23	1.36	1.42	2.730	44.1	46	27	20	207
207	304	100	44.0	.0038	27.8	7.4	.63	161.0	6.160	4.630	1.04	1.44	2.24	3.120	45.6	37	19	11	233
208	303	100	45.0	.0035	30.2	7.7	.67	145.0	5.460	4.080	2.58	1.52	2.05	2.660	42.0	34	18	12	236
209	308	100	35.0	.0040	23.1	5.8	.66	135.0	4.790	3.440	2.28	1.56	1.92	2.130	38.6	32	16	9	243
210	337	80	41.0	.0038	17.7	4.7	.43	175.0	5.920	4.550	2.12	1.46	1.79	2.580	14.5	72	62	54	112
211	305	100	52.0	.0036	26.6	5.4	.51	159.0	5.700	4.440	3.04	1.50	2.27	2.690	54.5	60	42	31	167
212	306	100	50.0	.0045	24.6	5.5	.50	165.0	6.070	4.540	2.28	1.42	1.75	2.750	55.0	63	47	36	154
213	332	79	30.0	.0034	13.6	4.0	.45	192.0	5.600	4.490	2.20	1.38	1.79	2.200	52.0	71	58	48	123
214	333	80	31.0	.0034	18.4	4.0	.45	192.0	5.600	4.490	2.20	1.38	1.79	2.200	52.0	71	58	48	123
215	334	80	31.0	.0034	18.4	4.0	.45	192.0	5.600	4.490	2.20	1.38	1.79	2.200	52.0	71	58	48	123
216	335	80	38.0	.0041	16.6	4.1	.44	190.0	5.410	4.230	2.18	1.56	1.87	2.110	50.7	77	67	59	109
217	377	100	42.0	.0034	22.8	6.7	.54	180.0	5.240	4.800	2.90	1.54	2.22	2.960	50.1	29	15	10	246
218	310	100	49.0	.0040	26.2	6.6	.53	189.0	5.920	4.320	2.96	1.72	2.24	2.950	43.1	30	15	9	246
219	297	100	38.0	.0032	20.0	6.3	.53	236.0	5.710	4.290	2.08	1.46	1.77	2.910	34.3	37	22	15	226
220	294	100	39.0	.0036	23.1	6.4	.58	278.0	5.560	3.930	2.02	1.40	2.16	2.660	36.2	54	37	29	180
221	299	100	41.0	.0037	23.8	6.4	.58	202.0	6.060	4.730	2.06	1.34	1.70	2.930	40.4	56	40	31	173
222	11	75	32.0	.0029	8.8	3.0	.28	256.0	1.880	3.740	1.26	.82	1.04	1.760	39.2	65	59	58	118
223	444	80	32.0	.0040	11.9	3.0	.37	194.0	4.700	3.720	1.68	.88	1.28	1.610	51.9	72	60	52	116
224	475	100	29.0	.0025	13.4	5.4	.46	192.0	5.130	3.670	2.54	1.18	1.86	2.540	41.5	44	31	25	200
225	476	100	35.0	.0031	20.6	6.6	.59	151.0	5.880	4.250	3.16	1.30	2.29	2.810	47.6	50	36	29	185
226	477	100	32.0	.0026	20.2	7.7	.63	137.0	6.270	4.700	3.26	1.48	2.32	3.200	54.3	54	41	34	171
227	478	100	32.0	.0033	14.0	4.2	.44	164.0	4.600	3.660	2.56	1.24	1.90	2.210	50.8	66	56	47	131
228	473	100	33.0	.0038	10.6	2.8	.32	225.0	4.400	3.020	2.24	1.12	1.88	1.520	42.0	78	68	63	91
229	479	100	35.0	.0028	21.4	7.6	.61	149.0	5.050	3.940	3.94	1.44	2.69	3.540	54.2	50	38	31	181
230	480	100	34.0	.0031	21.6	6.9	.63	138.0	6.180	4.650	3.58	1.42	2.50	2.960	53.6	62	48	39	151
231	482	100	37.0	.0033	21.0	6.4	.57	145.0	5.800	4.560	2.42	1.10	1.76	2.960	55.1	65	52	46	137
232	483	100	36.0	.0040	12.8	3.2	.36	221.0	4.200	3.400	2.06	1.52	1.59	1.830	42.7	71	60	64	105
233	474	100	35.0	.0043	10.8	2.5	.31	225.0	3.850	3.080	2.00	1.18	1.57	1.520	44.1	76	67	62	97
234	542	100	46.0	.0036	28.6	8.0	.62	150.0	6.620	4.600	2.74	1.28	2.01	3.350	49.5	46	32	28	194
235	543	100	37.0	.0030	21.6	7.3	.58	170.0	6.080	4.590	2.26	.92	1.59	3.230	46.6	49	36	30	185
236	544	100	34.0	.0030	20.6	6.9	.60	163.0	5.100	3.100	1.92	2.02	1.97	2.050	21.6	57	44	36	163
237	545	100	46.0	.0042	27.2	8.0	.63	140.0	6.280	4.630	2.62	1.16	1.89	2.960	56.2	69	57	49	135
238	521	100	60.0	.0061	25.8	4.2	.43	193.0	4.470	3.780	3.04	1.44	2.24	2.200	45.5	76	68	61	96
239	546	100	38.0	.0034	23.9	7.1	.63	135.0	6.360	4.720	2.16	1.00	1.58	3.220	55.5	58	47	38	157
240	547	100	42.0	.0035	25.4	7.3	.60	137.0	6.940	4.920	2.74	.92	1.97	3.260	59	59	51	33	185
241	548	100	39.0	.0039	15.0	3.8	.38	212.0	3.720	3.180	1.84	1.20	1.38	1.890	30.4	61	47	34	115

1 Commercial.

TABLE 7.—Quality tests—white spruce—Continued.

Grinder run No.	Paper machine run No.	Ground wood in total furnish.	Weight per ream.	Thickness.	Mullen test.				Schopper tests.						Tintometer indications.			
					Total.	Per 0.001 inch of thickness.	Per pound.	Horsepower per ton divided by strength factor.	Breaking length.		Stretch.		Breaking weight per square meter, sectional area.	Breaking length per horsepower	Red.	Green.	Blue.	Black.
					Points.	Points.	Points.		Meters.	Meters.	Per ct.	Per ct.	Grams.	Meters.	Parts.	Parts.	Parts.	Parts.
212	522	100	44.0	0.0046	17.6	3.8	0.40	203.0	2,550	4,230	2.22	1.04	1,920	41.7	77	69	61	93
213	623	80	34.0	0.0036	13.5	4.3	.46	272.0	2,110	4,640	2.10	1.33	2,370	35.0	80	72	65	83
214	622	80	38.0	0.0040	16.4	4.0	.43	226.0	2,530	4,930	2.68	1.36	2,040	38.4	80	71	65	84
215	672	80	36.0	0.0037	16.1	4.4	.45	188.0	3,140	4,640	1.96	1.16	2,340	55.0	78	68	64	90
216	652	80	37.0	0.0040	16.4	4.0	.44	221.0	3,060	4,340	2.86	1.06	1,930	43.3	74	67	62	87
217	624	80	36.0	0.0040	14.8	3.7	.41	259.0	2,610	4,960	2.22	1.40	2,780	26.2	78	71	63	88
218	625	80	41.0	0.0045	13.4	3.0	.33	202.0	2,350	4,250	2.22	1.22	1,700	48.6	76	70	64	90
219	666	80	44.0	0.0040	21.0	5.3	.48	394.0	3,280	5,380	2.28	1.14	2,700	23.4	71	63	56	110
220	662	80	34.0	0.0031	16.8	5.3	.52	281.0	3,380	6,660	2.58	1.44	2,880	32.7	67	61	57	96
221	627	80	33.0	0.0034	17.2	5.1	.49	281.0	2,870	6,110	2.58	1.24	2,640	30.7	70	64	57	112
222	660	80	37.0	0.0036	19.4	5.4	.52	414.0	3,370	6,730	1.86	1.30	2,840	23.5	73	64	58	105
223	661	80	37.0	0.0035	20.0	5.7	.54	330.0	3,580	6,660	2.72	1.30	3,000	28.7	76	66	60	96
224	626	80	40.0	0.0036	20.6	5.7	.52	394.0	3,180	6,270	2.72	1.30	2,960	23.0	77	68	62	95
225	657	84	35.0	0.0038	18.3	2.7	.47	312.0	2,650	4,690	1.98	1.02	1,780	40.5	59	49	43	149
226	633	80	40.0	0.0042	18.7	4.4	.47	274.0	3,030	5,140	2.22	1.10	2,270	32.4	77	68	60	95
227	644	80	36.0	0.0040	15.8	4.0	.44	336.0	3,000	5,270	2.16	1.10	2,270	32.4	75	70	63	92
228	648	80	36.0	0.0041	13.6	4.4	.38	253.0	3,460	4,500	1.38	.88	1,450	50.6	81	71	63	91
229	659	80	37.0	0.0044	10.5	2.4	.28	246.0	2,870	5,800	1.84	1.04	2,070	44.5	81	69	62	85
230	659	80	35.0	0.0039	13.9	3.5	.40	244.0	2,980	5,800	1.84	.92	1,840	52.5	77	69	63	89
231	679	80	33.0	0.0038	13.0	3.5	.39	214.0	2,870	5,800	1.84	.92	1,840	45.4	73	69	60	86
232	688	80	40.0	0.0046	14.8	3.2	.37	239.0	3,060	5,350	1.76	.82	1,960	54.7	80	70	65	102
233	680	80	39.0	0.0045	14.6	5.0	.45	130.0	2,420	5,680	1.48	1.06	2,650	69.5	73	69	64	86
234	705	100	40.0	0.0036	18.0	5.3	.48	119.0	2,160	5,710	1.10	1.04	2,470	74.0	47	32	27	194
235	704	100	38.0	0.0035	18.4	5.9	.48	111.0	2,350	6,180	1.28	1.14	2,650	68.8	50	35	30	185
236	703	100	38.0	0.0034	19.8	5.9	.52	111.0	2,350	6,180	1.28	1.14	2,650	73.8	50	35	30	174
237	697	100	45.0	0.0049	17.4	3.6	.26	188.0	2,280	4,910	1.28	1.00	1,880	62.6	55	45	45	138
238	733	80	33.0	0.0046	8.6	1.9	.39	127.0	2,050	4,180	1.42	1.00	1,130	73.7	77	69	61	93
239	733	80	45.0	0.0046	8.6	1.9	.39	127.0	2,050	4,180	1.42	1.00	1,130	73.7	77	69	61	93
240	707	100	39.0	0.0033	24.0	7.3	.62	104.0	3,620	7,540	2.54	1.06	3,680	86.5	30	30	30	181
241	698	100	34.0	0.0033	18.6	7.0	.55	103.0	2,630	6,580	1.42	1.10	2,910	81.0	37	37	30	181
242	696	100	43.0	0.0041	22.5	5.5	.52	112.0	2,890	5,800	1.88	1.00	2,700	74.4	50	37	31	182
243	702	100	46.0	0.0041	27.0	9.6	.58	99.0	5,190	6,170	3.22	1.38	3,000	81.5	59	42	36	163

274.....	699	100	41.0	.0044	17.8	4.1	.43	128.0	2,850	5,250	4,040	1.42	.88	1.15	2,140	73.3	64	53	46	137
275.....	664	100	46.0	.0057	9.2	1.6	.20	265.0	2,320	3,090	2,700	1.20	.82	1.01	1,220	51.0	76	68	61	95
276.....	710	80	33.0	.0042	9.6	2.3	.29	286.0	2,340	4,860	3,600	1.52	.94	1.23	1,540	41.9	84	74	67	75
277.....	665	80	37.0	.0048	9.3	2.0	.30	241.0	2,320	3,930	3,120	1.52	1.02	1.27	1,320	43.2	73	70	62	95
278.....	678	80	44.0	.0054	12.2	2.2	.28	186.0	2,460	4,680	3,570	1.38	.82	1.10	1,510	68.7	81	70	64	85
279.....	676	80	37.0	.0051	7.2	1.4	.19	242.0	1,820	3,360	2,590	1.20	.70	.95	1,950	56.3	81	71	64	84
280.....	714	80	38.0	.0046	12.7	2.7	.33	251.0	2,260	4,860	3,560	1.96	1.00	1.48	1,640	43.0	81	72	66	81
281.....	635	80	38.0	.0045	13.8	3.1	.36	236.0	2,960	4,950	3,960	2.36	.98	1.67	1,800	46.6	78	72	67	83
282.....	670	80	38.0	.0044	12.7	2.9	.33	312.0	2,310	5,410	4,110	2.00	1.02	1.51	1,900	39.9	75	66	62	97

¹ Pulps for runs 257 to 282, inclusive, were made on a coarse-grit stone.

TABLE 8.—Grinder runs on balsam fir.¹

Run No.	Preliminary treatment of wood.	Stone.		No. of pockets used.	Pressure on 1½-inch cylinder.	Pressure per square inch of pocket area.	Revolutions per minute.	Peripheral speed.	Average horsepower to grinder.	Maximum horsepower to grinder.	Bone-dry pulp in 24 hours.	Horsepower per ton bone-dry pulp in 24 hours.	Solid rossed wood ground in 24 hours.	Weight per cubic foot bone-dry wood.	Average diameter of wood.	Moisture in wood.	Bone-dry pulp per 100 cubic feet solid rossed wood.	Efficiency of conversion.	Screens per 100 cubic feet of rossed wood bone-dry.	Average temperature of grinding.	Horsepower divided by pressure × speed.
		Kind of burr.	Surface.		Lbs. per sq. in.	Lbs.	175	Fed per minute.	Lbs.	Tons.	Cu.ft.	Lbs.	Inch.	P. ct.	Lbs.	P. ct.	Lbs.	P. ct.	Lbs.	°F.	0.00949
1		Straight, cut 3 to 12 to inch.	Same as No. 7 tarack.	3	20	8.2	175	2,428	189.0	228	1,345	140.5	157.0	23.80	6	27.83	1,710	71.9	9.35	162.1	0.00949
2		do.	Same surface.	3	40	16.4	175	2,428	323.0	372	3,225	100.2	360.0	23.80	5½	27.83	1,792	75.4	19.88	155.0	.00811
3		do.	do.	3	60	24.65	175	2,428	470.0	541	5,695	82.6	661.0	23.80	5	27.83	1,720	72.3	41.25	150.0	.00785
4		Diamond point, cut 10 to inch.	Stone dressed.	3	20	8.2	175	2,428	161.6	178				23.08	5	34.76		76.6	137.8		
5		do.	Same surface.	3	40	16.4	175	2,428	311.0	344	1,749	178.0			5	34.76	1,770	8.65	175.3		.00781
6		do.	do.	3	60	24.65	175	2,428	424.0	495	3,495	121.3	371.5	23.08	5½	34.76	1,877	81.3	13.50	157.5	.00708
7	Steamed	Straight, cut 3 to 12 to inch; spiral, cut 12 to inch.	Same as poplar No. 1.	3	40	16.4	200	2,762	336.0	399	2,710	123.9	354.5	21.07	6½	59.45	1,530	72.5	23.20	146.7	.00741
8		do.	Same as for No. 925 spruce.	3	20	8.2	175	2,417	187.0	210	.835	224.0	86.8	21.44	4½	58.45	1,923	89.6	10.79	178.8	.00945
9		do.	Same surface.	3	40	16.4	175	2,417	336.0	378	2,525	133.0	260.0	21.44	4½	58.45	1,943	90.6	11.24	158.1	.00849
10		do.	do.	3	60	24.65	175	2,417	446.0	517	4,130	108.0	422.5	21.44	4	58.45	1,956	91.1	19.12	146.9	.00750
11		do.	do.	3	20	8.2	225	3,107	230.0	278	9,446	243.5	96.2	21.44	5	58.45	1,968	91.6	10.73	182.8	.00904
12		do.	do.	3	40	16.4	225	3,107	396.0	451	2,300	165.7	240.4	21.44	4	58.45	1,988	92.6	9.65	171.8	.00776
13		do.	do.	3	60	24.65	225	3,107	595.0	660	5,400	110.1	540.0	21.44	4	58.45	2,000	93.2	18.17	145.8	.00777
14		do.	Same as for poplar No. 2.	3	30	12.3	225	3,085	322.0	358	2,080	154.8	216.0	22.01	4	49.88	1,922	87.4	6.88	178.5	.00848
15	Boiled	Straight, cut 8 to 12 to inch.	Same as No. 15 Montana lodge-pole.	2	40	16.4	225	3,080	240.0	292	1,155	208.0	140.9	21.66	5½	51.23	1,640	75.6	21.45	143.9	.00475
16	do.	do.	Same surface.	2	60	24.65	225	3,080	317.0	383	1,830	173.2	212.0	21.66	5½	51.23	1,728	79.6	25.40	138.0	.00417
17	do.	do.	do.	2	80	32.8	225	3,080	374.0	440	2,227	167.8	264.0	21.66	5½	51.23	1,690	78.0	22.70	129.6	.00370
18		Straight, cut 3 to 12 to inch; spiral, cut 12 to inch.	Same as for No. 15 western yellow pine.	3	60	24.65	100	1,366	275.0	306	2,242	122.8	264.0	21.20	5½	48.75	1,698	80.0	15.43	97.0	.00816
19		do.	Same surface.	3	60	24.65	150	2,049	400.0	449	3,320	120.4	354.0	21.20	4½	48.75	1,876	88.5	19.06	129.5	.00790
20		do.	do.	3	60	24.65	200	2,732	496.0	553	3,880	128.0	428.0	21.20	5½	48.75	1,814	85.5	15.80	139.6	.00736

21	Straight, cut 2 to inch, spiral, cut 12 to inch.	3	60	24.65	250	3,415	551.0	630	4.325	127.6	463.0	21.20	5 $\frac{1}{2}$	48.75	1,870	88.1	19.20	147.6	.00654
22	Spiral, cut 8 to inch; straight, cut 10 to inch.	3	40	16.4	225	3,069	481.0	543	5.330	90.4	546.0	20.75	4 $\frac{1}{2}$	60.40	1,650	94.1	8.45	150.4	.00955
23	Spiral, cut 8 to inch; straight, cut 10 to inch.	2	60	16.4	175	2,387	333.0	372	3.225	103.1	338.0	20.20	5 $\frac{1}{2}$	61.66	1,910	94.5	18.60	148.0	.00850
24	Same as No. 4 En- gelmannspruce.																		
25	Steamed. Spiral, cut 8 to inch; straight, cut 10 to inch.	2	20	8.2	225	3,048	137.0	171	.953	144.0	113.0	19.92	5 $\frac{3}{8}$	61.08	1,680	84.4	13.40	150.0	.00548
26	do.	2	40	16.4	225	3,048	246.0	286	2.302	106.8	270.0	19.92	5 $\frac{1}{2}$	61.08	1,710	85.9	17.30	133.0	.00491
27	do.	2	60	24.65	225	3,048	311.0	355	3.105	100.0	374.0	19.92	5 $\frac{3}{8}$	61.08	1,660	83.3	20.30	136.0	.00414
28	do.	2	80	32.8	225	3,048	371.0	414	3.755	98.9	441.0	19.92	5 $\frac{3}{8}$	61.08	1,700	85.3	30.60	134.0	.00371
29	do.	2	100	41.0	225	3,048	413.0	491	4.050	102.0	479.0	19.92	5 $\frac{3}{8}$	61.08	1,695	85.0	27.50	136.0	.00330

¹ For conditions of cooking see Table 32.² See Runs on mixed woods (commercial).

TABLE 9.—Grinder runs on red fir.¹

Run No.	Preliminary treatment of wood.	Stone.		Number of pockets used.	Pressure on 14-inch cylinder.	Pressure per square inch of pocket area.	Revolutions per minute.	Peripheral speed.	Average horsepower to grinder.	Maximum horsepower to grinder.	Bone-dry pulp in 24 hours.	Horsepower per ton bone-dry pulp in 24 hours.	Solid ground in 24 hours.	Weight per cubic foot bone-dry wood.	Average diameter of wood.	Moisture in wood.	Bone-dry pulp per 100 cubic feet solid ground wood.	Efficiency of conversion.	Screenings per 100 cubic feet solid ground wood.	Average temperature of grinding.	Horsepower divided by pressure X speed.
		Kind of burr.	Surface.		Lbs. per sq. in.	Lbs.		Ft. per minute.			Tons.	Cu. ft.					P. ct.	Lbs.	P. ct.	Lbs.	° F.
1		Straight, cut 3 to 12 to inch.	Same as for spruce No. 41.	3	50	20.5	200	2,775	420.0	489	6.450	65.2	672.0	21.93	(²)	16.98	1,920	87.6	10.94	133.0	0.00739
2	Steamed	.....	Same as spruce No. 72.	3	40	16.4	200	2,762	288.5	370	2.299	125.7	297.0	23.76	(²)	15.63	1,547	65.1	17.76	166.3	.00036
3		do.	Same as California lodgepole No. 2.	3	30	12.3	225	3,085	325.0	374	Qualitative run.				(²)	.....	.....	.....	.....	165.1	.00856
4		do.	Same as balsam No. 14.	3	30	12.3	225	3,085	304.0	370	1.080	181.0	169.0	24.35	(²)	11.17	1,988	81.6	12.31	178.0	.00800
5		do.	Same as California lodgepole No. 3.	3	60	24.65	225	3,085	521.0	574	2.565	203.5	302.0	24.47	(²)	22.40	1,700	69.5	9.83	176.2	.00685
6		do.	Same as for No. 8 western hemlock.	3	60	24.65	100	1,366	244.0	262	1.161	210.0	128.0	21.85	(²)	20.13	1,815	83.0	19.10	157.2	.00725
7		do.	Same surface	3	60	24.65	150	2,049	366.0	434	1.088	337.0	136.6	21.85	(²)	20.13	1,590	72.7	12.38	175.3	.00724
8		do.	do.	3	60	24.65	200	2,732	425.0	485	1.379	308.0	162.0	21.85	(²)	20.13	1,698	77.6	11.10	178.2	.00630
9		do.	do.	3	60	24.65	250	3,415	566.0	647	2.188	258.5	312.0	21.85	(²)	20.13	1,400	64.0	9.60	181.0	.00673
10		do.	Same as larch No. 4.	2	20	8.2	225	3,073	153.4	177	.492	312.0	62.5	21.02	(²)	22.72	1,872	89.0	6.40	154.1	.00609
11		do.	Same surface	2	40	16.4	225	3,073	246.0	303	1.165	211.0	130.0	21.02	(²)	22.72	1,700	85.1	7.98	166.3	.00489
12		do.	do.	2	60	24.65	225	3,073	376.0	450	1.737	216.5	212.0	21.02	(²)	22.72	1,688	77.8	9.90	166.2	.00496
13		do.	do.	2	80	32.8	225	3,073	459.0	543	2.500	133.4	265.0	21.02	(²)	22.72	1,890	89.9	8.51	156.5	.00455
14		do.	do.	2	100	41.0	225	3,073	475.0	576	3.275	145.0	362.0	21.02	(²)	22.72	1,810	86.0	16.72	155.7	.00377
15		Spiral, cut 8 to 10 in ch; straight, cut 10 to inch.	Same as No. 52 tamarack.	2	40	16.4	225	3,069	238.0	286	1.627	146.3	165.0	21.60	(²)	28.87	1,970	91.2	7.76	158.0	.00472

16	do.	21	60	24.65	225	3,069	352.0	428	2.806	125.2	282.0	21.60	(3)	28.87	1,998	92.4	9.70	157.7	.00465
17	do.	21	80	32.8	225	3,069	402.0	527	4.570	101.1	446.0	21.60	(3)	28.87	2,043	94.6	11.26	149.0	.00459
18	do.	21	100	41.0	225	3,069	500.0	632	5.540	101.0	540.0	21.60	(3)	28.87	2,050	94.9	10.37	151.7	.00445
19	do.	21	80	32.8	225	3,069	483.0	580	5.710	84.6	571.0	21.59	(2)	26.50	2,000	92.7	12.60	158.0	.00479

¹ For conditions of cooking see Table 32.

² Split wood.

Same surface...
do.
do.
do.
Same as for No.
26 California
lodgepole.

TABLE 10.—Grinder runs on white fir.¹

Run No.	Preliminary treatment of wood.	Stone.		Number of pockets used.	Pressure on 14-inch cylinder.	Tressure per square inch of pocket area.	Revolutions per minute.	Peripheral speed.	Average horsepower to grinder.	Maximum horsepower to grinder.	Bone-dry pulp in 24 hours.	Horsepower per ton bone-dry pulp in 24 hours.	Solid ground in 24 hours.	Weight per cubic foot bone-dry wood.	Average diameter of wood.	Moisture in wood.	Bone-dry pulp per 100 cubic feet solid ground wood.	Efficiency of conversion.	Screenings per 100 cubic feet solid ground wood.	Average temperature of grinding.	Horsepower divided by pressure × speed.
		Kind of burr.	Surface.		Lbs. per sq. in.	Lbs.	° F. per minute.				Tons.	Cu. ft.	Lbs.	Lbs.	Inches.	P. ct.	Lbs.	P. ct.	Lbs.	° F.	0.00607
1		Spiral, cut 8 to 10 to inch.	Same as No. 3, Engelmann spruce, Colo.	2	60	24.65	225	3,069	306	342	2,319	132.0	245	19.47	(2)	64.80	1,892	97.2	17.3	155	0.00607
2		do.	do.	2	60	24.65	225	3,069	385	442	3,575	107.7	370	19.47	(2)	64.80	1,930	99.1	21.3	150	.00509
3		do.	do.	2	80	32.8	225	3,069	469	559	5,295	88.5	529	19.47	(2)	64.80	2,000	102.8	22.6	142	.00465
4		do.	do.	3	60	24.65	100	1,355	276	318	3,180	86.8	296	22.17	(2)	48.76	2,150	97.0	10.7	146	.00825
5		do.	do.	3	60	24.65	150	2,033	362	427	3,990	90.7	394	22.17	(2)	48.76	2,025	91.5	12.6	150	.00722
6		do.	do.	3	60	24.65	200	2,710	503	609	5,885	85.5	662	22.17	(2)	48.76	1,775	80.1	9.4	135	.00752
7		do.	do.	3	60	24.65	250	3,388	556	661	6,650	83.7	582	22.17	(2)	48.76	2,280	102.9	11.5	136	.00665
8		do.	do.	2	40	16.4	175	2,372	223	268	1,921	115.9	189	21.42	(2)	45.50	2,030	94.7	13.6	151	.00574
9		do.	do.	2	60	24.65	175	2,372	291	345	2,880	101.0	302	21.42	(2)	45.50	1,910	89.1	15.2	155	.00497
10		do.	do.	2	80	32.8	175	2,372	374	440	4,020	93.1	383	21.42	(2)	45.50	2,100	98.0	17.2	148	.00480
11		do.	do.	2	100	41.0	175	2,372	407	482	4,775	85.2	477	21.42	(2)	45.50	2,000	93.2	20.2	143	.00419
12		do.	do.	2	40	16.4	175	2,372	244	260	2,055	109.0	194	22.76	(2)	50.88	2,120	93.2	8.5	130	.00627
13		do.	do.	2	60	24.65	175	2,372	313	350	2,897	108.0	274	22.76	(2)	50.88	2,110	92.9	16.2	154	.00635
14		do.	do.	2	80	32.8	175	2,372	390	449	4,470	87.2	438	22.76	(2)	50.88	2,040	89.7	9.6	145	.00501
15		do.	do.	2	100	41.0	175	2,372	443	516	5,250	84.4	500	22.76	(2)	50.88	2,100	92.4	14.6	142	.00455
16		do.	do.	3	40	16.4	175	2,372	218	274	(2)	(2)	(2)	(2)	(2)	49.97	(2)	(2)	(2)	133	.00560
17		do.	do.	2	40	16.4	175	2,372	232	280	2,160	107.2	229	20.82	(2)	49.97	1,888	90.5	5.3	147	.00596
18		do.	do.	2	60	24.65	175	2,372	325	365	3,255	100.0	364	20.82	(2)	49.97	1,790	85.9	12.6	151	.00555
19		do.	do.	2	80	32.8	175	2,372	395	465	4,630	85.4	476	20.82	(2)	49.97	1,945	93.4	14.6	151	.00508
20		do.	do.	2	100	41.0	175	2,372	467	558	6,210	75.2	681	20.82	(2)	49.97	1,825	87.5	15.5	141	.00480
21	Steamed.	do.	do.	2	40	16.4	200	2,710	231	271	1,925	120.0	238	20.82	(2)	49.97	1,620	77.7	30.0	143	.00520
22	do.	do.	do.	2	60	24.65	206	2,794	320	364	2,005	114.0	375	20.82	(2)	49.97	1,490	71.5	21.5	144	.00465
23	do.	do.	do.	2	80	32.8	209	2,885	395	449	4,005	98.6	488	20.82	(2)	49.97	1,645	79.1	27.6	139	.00425
24	do.	do.	do.	2	100	41.0	210	2,845	468	555	4,815	97.1	617	20.82	(2)	49.97	1,560	74.9	28.8	134	.00401
25	do.	do.	do.	3	60	24.65	198	2,682	322	371	3,370	95.5	388	20.82	(2)	49.97	1,740	83.5	25.0	134	.00486
26	do.	do.	do.	3	60	24.65	189	2,561	320	372	3,585	89.2	395	20.82	(2)	49.97	1,813	87.0	27.2	137	.00506

27	do.....	2	60	24.65	100	1,355	195	226	1,725	113.0	179	21.85	(2)	38.90	1,930	88.3	10.0	.00584
28	do.....	2	60	24.65	150	2,033	280	326	2,630	107.3	249	21.85	(2)	38.90	2,093	95.6	13.3	.00559
29	do.....	2	60	24.65	200	2,710	351	395	3,037	97.0	337	21.85	(2)	38.90	2,030	92.8	13.4	.00570
30	do.....	2	60	24.65	250	3,388	449	500	4,755	94.5	445	21.85	(2)	38.90	2,140	97.9	6.5	.00536
31	do.....	2	60	24.65	100	1,355	196	231	1,750	112.0	171	22.18	(2)	34.15	2,040	92.0	15.7	.00586
32	do.....	2	60	24.65	150	2,033	280	329	2,298	122.0	225	22.18	(2)	34.15	2,040	92.0	14.0	.00559
33	do.....	2	60	24.65	200	2,710	400	459	3,500	114.2	338	22.18	(2)	34.15	2,075	93.5	27.0	.00599
34	do.....	2	60	24.65	250	3,388	455	509	3,945	115.0	393	22.18	(2)	34.15	2,005	90.5	12.9	.00544
35	Spiral, cut 8 to inch; straight, cut 10 to inch.	3	45	18.5	225	3,020	384	477	4,775	80.4	498	20.80	(2)	20.58	1,920	92.2	16.4	.00087

No production data.

Split wood.

¹ For conditions of cooking see Table 32.

TABLE 11.—Grinder runs on Alpine fir.¹

Run No.	Preliminary treatment of wood.	Stone.		Number of pockets used.	Pressure on 14-inch cylinder.	Pressure per square inch of pocket area.	Revolutions per minute.	Peripheral speed.	Average horsepower to grinder.	Maximum horsepower to grinder.	Bone-dry pulp in 24 hours.	Horsepower per ton bone-dry pulp in 24 hours.	Solid ground in 24 hours.	Weight per cubic foot bone-dry wood.	Average diameter of wood.	Moisture in wood.	Bone-dry pulp per 100 cubic feet solid tressed wood.	Efficiency of conversion.	Screenings per 100 cubic feet solid tressed wood.	Average temperature of grinding.	Horsepower divided by pressure $\times$ speed.
		Kind of burr.	Surface.		Lbs. per sq. in.	Lbs.	Ft. per minute.				Tons.	Cu. ft.	Lbs.	Lbs.	Inches.	P. ct.	Lbs.	P. ct.	Lbs.	° F.	
1	.....	Diamond point, 6 to inch; spiral, cut 12 to inch.	Same as No. 14, amabilis fir.	2	40	16.40	225	3,049	312	371	2.647	117.7	252	22.30	6 $\frac{1}{2}$	47.25	2,095	93.9	6.35	148	0.06524
2	.....	do.	Same surface.	2	60	24.65	225	3,049	412	469	4.430	93.0	429	22.30	7 $\frac{1}{2}$	47.25	2,065	92.6	14.10	137	.00548
3	.....	do.	do.	2	80	32.80	225	3,049	513	591	6.510	78.7	627	22.30	7 $\frac{1}{2}$	47.25	2,078	93.0	27.80	131	.00513
4	.....	do.	do.	2	100	41.00	225	3,049	611	660	8.050	73.9	795	22.30	7 $\frac{1}{2}$	47.25	2,022	90.7	21.80	127	.00490
5	.....	Spiral, cut 12 to inch; straight, cut 3 to inch.	Stone dressed...	2	60	24.65	100	1,355	204	233	2.045	99.7	207	22.30	6 $\frac{1}{2}$	47.25	1,977	88.6	16.90	140	.00611
6	.....	do.	Same surface.	2	60	24.65	150	2,033	320	361	3.280	97.5	319	22.30	6 $\frac{1}{2}$	47.25	2,056	92.1	16.10	147	.00638
7	.....	do.	do.	2	60	24.65	200	2,710	365	420	3.940	92.6	369	22.30	6 $\frac{1}{2}$	47.25	2,135	95.6	14.30	139	.00546
8	.....	do.	do.	2	60	24.65	250	3,388	465	509	5.435	85.6	533	22.30	7	47.25	2,038	91.4	14.30	133	.00556
9	Steamed.	do.	do.	2	40	16.40	225	3,049	264	317	2.125	124.0	242	22.30	7 $\frac{1}{2}$	47.25	1,757	78.8	34.40	134	.00528
10	do.	do.	do.	2	60	24.65	225	3,049	357	410	3.775	94.7	413	22.30	7	47.25	1,830	82.1	70.50	120	.00475
11	do.	do.	do.	2	80	32.80	225	3,049	420	497	4.715	89.0	526	22.30	7	47.25	1,788	80.1	91.90	120	.00420
12	do.	do.	do.	2	100	41.00	225	3,049	475	537	5.375	88.4	629	22.30	6 $\frac{1}{2}$	47.25	1,710	76.7	101.00	117	.00380
13	do.	do.	Stone dressed...	3	50	20.50	225	3,020	430	579	5.110	84.0	479	21.60	7 $\frac{1}{2}$	43.00	2,135	98.9	16.2	156	.00695

¹ For conditions of cooking see Table 32.

TABLE 12.—Grinder runs on *anabitis* fir.¹

GROUND-WOOD PULP.

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Run No.	Stone.		Number of pockets used.	Pressure on 14-inch cylinder.	Pressure per square inch of pocket area.	Revolutions per minute.	Peripheral speed.	Average horsepower to grinder.	Maximum horsepower to grinder.	Bone-dry pulp in 24 hours.	Horsepower per ton bone-dry pulp in 24 hours.	Solid ground in 24 hours.	Weight per cubic foot bone-dry wood.	Average diameter of wood.	Moisture in wood.	Bone-dry pulp per 100 cubic feet solid ground wood.	Efficiency of conversion.	Screenings per 100 cubic feet solid ground wood bone-dry.	Average temperature of grinding.	Horsepower divided by pressure X speed.
	Preliminary treatment of wood.	Kind of burr.																		
1	.....	Diamond point, 6 to inch; spiral, cut 12 to inch.	2	Lbs. per sq. in. 40	Lbs. 16.40	225	Ft. per minute. 3,049	296	349	Tons. 3.200	92.5	Cu. ft. 339	Lbs. 20.96	Inches. (2)	P. ct. 47.56	Lbs. 1,888	P. ct. 90.1	Lbs. 5.60	° F. 145	0.00591
2	.....	Stone dressed....	2	60	24.65	225	3,049	398	455	4.930	80.8	518	20.96	(2)	47.56	1,905	91.0	8.43	142	.00529
3	.....	Same surface....	2	80	32.80	225	3,049	484	569	6.850	70.6	735	20.96	(2)	47.56	1,863	89.0	10.20	132	.00484
4	.....	do.....	2	100	41.00	225	3,049	581	670	8.760	66.3	975	20.96	(2)	47.56	1,800	86.0	12.40	138	.00465
5	.....	do.....	2	60	24.65	100	1,355	195	228	2.170	90.0	233	20.96	(2)	47.56	1,862	89.0	10.50	140	.00584
6	.....	do.....	2	60	24.65	150	2,033	275	330	2.945	93.5	332	20.96	(2)	47.56	1,773	84.7	8.05	142	.00549
7	.....	do.....	2	60	24.65	200	2,710	376	432	4.125	91.2	401	20.96	(2)	47.56	1,790	85.5	9.00	147	.00563
8	.....	do.....	2	60	24.65	250	3,388	454	509	5.800	78.2	596	20.96	(2)	47.56	1,948	93.0	13.60	137	.00543
9	Steamed	do.....	2	40	16.40	225	3,049	223	282	1.728	129.0	226	20.96	(2)	47.56	1,530	73.0	20.60	131	.00445
10	.....	do.....	2	60	24.65	225	3,049	320	381	3.225	99.2	421	20.96	(2)	47.56	1,532	73.1	34.00	124	.00425
11	.....	do.....	2	80	32.80	225	3,049	368	447	3.530	104.0	408	20.96	(2)	47.56	1,510	72.1	40.90	123	.00347
12	do.....	do.....	2	100	41.00	225	3,049	434	514	4.430	98.0	589	20.96	(2)	47.56	1,505	71.9	38.20	120	.00348
13	do.....	do.....	2	60	24.65	211	2,465	324	394	2.920	111.0	352	20.96	(2)	47.56	1,660	79.2	18.90	138	.00459
14	do.....	do.....	2	60	24.65	181	2,435	323	390	3.240	99.7	355	20.96	(2)	47.56	1,822	87.0	14.00	138	.00534
15	.....	Spiral, cut 8 to inch; straight, cut 10 to inch.	2	80	32.80	225	3,029	397	502	4.900	81.0	435	21.10	(2)	25.27	2,020	95.7	10.30	159	.00401

² Split wood.¹ For conditions of cooking see Table 32.

TABLE 13.—Grinder runs on lowland fir (Montana).¹

Run No.	Preliminary treatment of wood.	Stone.		Number of pockets used.	Lbs. per sq. in.	Pressure per square inch of pocket area.	Revolutions per minute.	Peripheral speed, Ft. per minute.	Average horsepower to grinder.	Maximum horsepower to grinder.	Bone-dry pulp in 24 hours.	Horsepower per ton bone-dry pulp in 24 hours.	Solid ground in 24 hours.	Weight per cubic foot bone-dry wood.	Average diameter of wood.	Moisture in wood.	Bone-dry pulp per 100 cubic feet solid rossed wood.	Efficiency of conversion.	Screenings per 100 cubic feet solid rossed wood.	Average temperature of grinding.	Horsepower divided by pressure X speed.
		Kind of burr.	Surface.																		
1	Steamed..	Spiral, cut 8 to 1 in. ch; straight, cut 10 to 1 in. ch.	Stone dressed....	2	60	24.65	175	2,348	157	195	1,855	84.6	224	21.40	81	48.00	1,660	77.5	21.6	°F. 122	0.00407
2	do.....	do.....	Same surface.....	2	60	24.65	175	2,348	221	273	2,765	80.0	344	21.40	81	48.00	1,610	75.2	32.9	119	.00382
3	do.....	do.....	do.....	2	80	32.80	175	2,348	283	342	3,445	82.1	409	21.40	8	48.00	1,683	78.7	25.7	119	.00367
4	do.....	do.....	do.....	2	60	24.65	175	2,348	207	260	2,980	69.5	320	21.40	8	48.00	1,862	87.0	7.6	136	.00338
5	do.....	do.....	do.....	2	60	24.65	175	2,348	280	322	4,465	62.6	475	21.40	8	48.00	1,880	87.9	8.4	136	.00383
6	do.....	do.....	do.....	2	80	32.80	175	2,348	347	387	5,650	61.4	605	21.40	8	48.00	1,870	87.4	8.7	127	.00483
7	do.....	do.....	do.....	2	40	16.40	100	1,342	141	176	1,730	81.5	192	21.40	8	48.00	1,805	84.3	5.7	139	.00840
8	do.....	do.....	do.....	2	40	16.40	150	2,013	185	218	2,290	80.7	240	21.40	8	48.00	1,910	89.2	8.2	143	.00561
9	do.....	do.....	do.....	2	40	16.40	200	2,684	226	276	2,735	82.8	290	21.40	8	48.00	1,888	88.1	5.5	139	.00513
10	do.....	do.....	do.....	2	40	16.40	250	3,355	255	317	3,405	74.9	370	21.40	8	48.00	1,837	83.8	5.5	136	.00464
11	do.....	do.....	do.....	2	40	16.40	175	2,348	213	258	2,345	90.8	234	21.65	66	46.40	2,000	92.4	4.9	142	.00553
12	do.....	do.....	Same surface.....	2	60	24.65	175	2,348	294	329	3,750	78.4	366	21.65	62	46.40	2,045	94.5	6.3	138	.00507
13	do.....	do.....	do.....	2	80	32.80	175	2,348	358	413	3,100	70.3	488	21.65	7	46.40	2,090	96.5	4.9	139	.00465
14	do.....	do.....	do.....	2	60	24.65	150	1,342	192	226	2,315	83.0	331	21.65	6	46.40	2,060	95.1	4.8	132	.00580
15	do.....	do.....	do.....	2	60	24.65	150	2,013	273	311	3,245	84.2	329	21.65	7	46.40	1,970	91.0	4.8	140	.00551
16	do.....	do.....	do.....	2	60	24.65	200	2,684	333	403	4,265	82.6	409	21.65	66	46.40	2,090	96.5	5.2	138	.00533
17	do.....	do.....	do.....	2	60	24.65	250	3,355	384	436	4,790	80.3	492	21.65	66	46.40	1,941	89.7	4.4	142	.00465

¹ For conditions of cooking see Table 32.

TABLE 14.—Grinder runs on noble fir.¹

Run No.	Preliminary treatment of wood.	Stone.		Number of pockets used.	Pressure on 14-inch cylinder.	Pressure per square inch of pocket area.	Revolutions per minute.	Peripheral speed.	Average horsepower to grinder.	Maximum horsepower to grinder.	Bone-dry pulp in 24 hours.	Horsepower per ton bone-dry pulp in 24 hours.	Solid ground in 24 hours.	Weight per cubic foot bone-dry wood.	Average diameter of wood.	Moisture in wood.		Bone-dry pulp per 100 cubic feet solid ground wood.	Efficiency of conversion.	Screenings per 100 cubic feet solid ground wood.	Average temperature of grinding.	Horsepower divided by pressure X speed.
		Kind of burr.	Surface.													P. ct.	Lbs.					
1		Spiral, cut 8 to inch; straight, cut 10 to inch.	Stone dressed....	2	Lbs. per sq. in. 40	Lbs. 16.40	225	Ft. per minute. 3,020	222	307	Tons. 1.980	112.0	Cu. ft. 216	Lbs. 21.05	Inches.	P. ct. 34.80	Lbs. 1,835	P. ct. 87.1	Lbs. 17.4	° F. 143	0.00449	
2		do.	Same surface.	2	60	24.65	225	3,020	290	413	3.410	85.0	345	21.05	.....	34.80	1,980	94.0	20.1	131	.00389	
3		do.	do.	2	80	32.80	225	3,020	406	487	5.100	79.6	487	21.05	.....	34.80	2,090	92.2	18.9	131	.00410	
4		do.	do.	2	100	41.00	225	3,020	470	581	6.750	69.5	581	21.05	.....	34.80	1,950	92.6	22.6	118	.00380	
5		do.	do.	2	60	24.65	100	1,342	190	218	2.275	83.5	252	21.05	.....	34.80	1,805	85.7	22.0	125	.00574	
6		do.	do.	2	60	24.65	150	2,013	233	284	2.920	79.8	311	21.05	.....	34.80	1,875	89.0	16.5	123	.00470	
7		do.	do.	2	60	24.65	200	2,684	290	370	3.340	86.8	336	21.05	.....	34.80	1,990	94.5	15.7	132	.00437	
8	Steamed.	do.	do.	2	60	24.65	230	3,355	336	392	3.990	84.2	386	21.05	.....	34.80	2,060	97.9	11.2	128	.00406	
9	do.	do.	do.	2	40	16.40	225	3,020	189	256	1.990	95.5	272	21.05	.....	34.80	1,465	69.6	33.6	121	.00382	
10	do.	do.	do.	2	60	24.65	225	3,020	271	326	2.965	91.3	441	21.05	.....	34.80	1,342	63.8	82.1	116	.00364	
11	do.	do.	do.	2	80	32.80	225	3,020	314	407	3.290	95.5	437	21.05	.....	34.80	1,502	71.4	89.5	112	.00317	
12	do.	do.	do.	2	60	24.65	225	3,020	296	382	2.930	101.0	315	21.05	.....	34.80	1,860	88.4	44.4	123	.00398	
13	do.	do.	do.	2	60	24.65	225	3,020	313	356	4.070	76.9	414	21.05	.....	34.80	1,969	93.5	16.4	123	.00421	
14	do.	do.	Same as No. 256 spruce.	2	80	32.80	225	3,020	438	492	5.390	81.4	564	20.96	.....	36.60	1,916	91.5	21.0	130	.00443	
15		do.	do.	2	80	32.80	225	3,020	415	462	4.450	93.2	456	21.20	.....	33.25	1,950	92.0	21.2	132	.00419	
16		do.	Stone dressed.	3	50	20.50	225	3,020	393	504	4.275	92.0	442	21.05	.....	34.80	1,933	91.9	14.8	151	.00635	
17		Straight, cut 3 to inch; spiral, cut 12 to inch.	Same as No. 275 spruce.	2	40	16.40	200	2,774	277	319	4.560	60.7	571	21.05	.....	34.80	1,595	75.7	332.0	117	.00609	
18		do.	Same as No. 17.	2	20	8.20	200	2,774	155	195	2.150	72.0	220	21.05	.....	34.80	1,950	92.6	35.9	130	.00682	

¹ For conditions of cooking see Table 34.

Nos. 17 and 18 were run on a coarse-grit stone.

29	do.	Same surface.	3	50	20.5	175	2, 435	372.0	417.0	3.900	81.8							187.0
30	Straight, cut 10 to 12 to inch.	Stone dressed.	3	40	16.4	175	2, 435	319.0	389.0	3.900								145.0
31	do.	do.	3	60	24.65	100	1, 390	299.0	344.0	3.330	80.9							145.0
32	do.	do.	3	60	24.65	100	1, 390	298.0	363.0	3.120	95.5							155.0
33	do.	do.	3	50	20.5	175	2, 435	376.0	500.0	4.000	94.0							163.0
34	Spiral, cut 4 to inch.	Same surface.	3	60	24.65	100	1, 390	297.0	342.0	4.350	68.3							135.0
35	do.	do.	3	60	24.65	100	1, 390	284.0	342.0	2.915	97.5							137.0
36	do.	do.	3	60	24.65	150	2, 090	417.0	489.0	5.130	81.4							147.0
37	do.	do.	3	60	24.65	200	2, 782	520.0	630.0	6.890	75.5							152.0
38	do.	do.	3	50	20.5	84	1, 173	212.0	241.0	2.660	79.7							154.0
39	do.	do.	3	60	24.65	85	1, 183	271.0	313.0	2.955	91.8							154.0
40	do.	do.	3	50	20.5	100	1, 390	285.0	330.0	3.025	94.3							150.0
41	do.	do.	3	50	20.5	150	2, 090	379.0	440.0	4.450	85.2							156.0
42	do.	do.	3	50	20.5	175	2, 435	429.0	506.0	5.295	81.1							155.0
43	do.	do.	3	50	20.5	200	2, 782	439.0	545.0	5.425	80.9							145.0
44	do.	do.	3	40	16.4	175	2, 435	359.0	411.0	4.225	85.0							158.0
45	Straight, cut 3 to inch.	Stone dressed.	3	40	16.4	200	2, 800	340.0	417.0	2.915	116.5							159.0
47	do.	do.	3	55	22.6	200	2, 800	516.0	594.0	5.370	96.2							161.0
48	do.	do.	3	50	20.5	225	3, 145	510.0	579.0	6.235	81.8							164.0
50	Straight, cut 3 to inch, spiral, cut 12 to inch.	Stone dressed.	3	50	20.5	175	2, 445	422.5	488.0	3.300	79.7	512.0	24.84	46.53	2,070	83.5		170.6
51	do.	do.																
52	do.	do.																
53	Steamed.	Same as for jack pine No. 25.	3	40	16.4	250	3, 460	428.0	504.0	5.655	75.7	536.0	26.34	54	39.61	2,110	80.1	27.90
54	Boiled.	Stone dressed.	3	40	16.4	200	2, 762	307.0	364.0	4.155	73.9	421.0	24.34	64	44.11	1,972	81.1	18.86
55	Steamed.	Same as for jack pine No. 26.	3	40	16.4	200	2, 762	313.0	367.0	2.525	124.0	290.0	25.10	64	45.27	1,741	69.4	24.65
56	do.	Same as for jack pine No. 27.	3	30	12.3	225	3, 085	300.0	342.0	1.430	210.0	142.7	25.68	64	41.63	2,005	78.1	6.59
57	do.	Same as for western hemlock No. 4.	3	20	8.2	250	3, 427	222.5	259.0	1.305	170.8	136.7	24.90	54	45.36	1,910	76.7	8.59
58	do.	Same surface.	3	40	16.4	250	3, 427	390.0	450.0	3.485	112.0	340.0	24.90	6	45.36	2,050	82.4	8.84
59	do.	do.	3	60	24.65	250	3, 427	511.0	630.0	3.580	97.0	561.0	24.90	54	45.36	1,990	80.0	12.90
60	Boiled.	Same as jack pine No. 20.	2	40	16.4	225	3, 080	220.0	275.0	1.118	197.2	143.2	23.75	54	45.31	1,560	65.7	12.30
61	do.	Same surface.	2	60	24.65	225	3, 080	315.0	352.0	2.379	132.5	281.0	23.75	54	45.31	1,694	71.4	17.76
62	do.	do.	2	80	32.8	225	3, 080	358.0	431.0	2.755	130.3	336.0	23.75	54	45.31	1,640	69.1	25.90
63	do.	do.																142.0

² See Commercial runs on mixed woods.

¹ For conditions of cooking see Table 32.
NOTE.—For runs 46 (a, b, and c) and 49 (a and b) see for runs on mixed woods.

TABLE 16.—Grinder runs on western hemlock.¹

Run No.	Stone.		Number of pockets used.	Pressure on 14-inch cylinder.	Pressure per square inch of pocket area.	Revolutions per minute.	Peripheral speed.	Average horsepower to grinder.	Maximum horsepower to grinder.	Bone-dry pulp in 24 hours.	Horsepower per ton bone-dry pulp in 24 hours.	Solid ground in 24 hours.	Weight per cubic foot bone-dry wood.	Average diameter of wood.	Moisture in wood.		Bone-dry pulp per 100 cubic feet solid rosed wood.	Efficiency of conversion.	Screenings per 100 cubic feet solid rosed wood.	Average temperature of grinding.	Horsepower divided by pressure $\times$ speed.																																																																																																																																																																																																																																																																			
	Kind of burr.	Surface.													P. ct.	Lbs.																																																																																																																																																																																																																																																																								
1	Preliminary treatment of wood.	Straight, cut 3 to inch; spiral, cut 12 to inch.	3	Same as for Sitka spruce No. 1.	Lbs. per sq. in. 30	12.30	225	3,085	305	354	2,270	134.5	218.0	24.40	Inches. (2)	27.73	2,080	85.2	10.91	178.9	0.00803																																																																																																																																																																																																																																																																			
2																						Same as for Sitka spruce No. 4.	8	20	8.20	250	3,427	218	258	1,715	127.0	144.0	28.35	(2)	24.15	2,380	84.0	8.85	161.1	.00775																																																																																																																																																																																																																																																
3																																									Same surface.	3	40	16.40	250	3,427	326	391	3,480	93.7	288.0	28.35	(2)	24.15	2,420	85.4	13.50	154.3	.00580																																																																																																																																																																																																																													
4																																																												do.	3	60	24.65	250	3,427	552	625	5,850	94.4	524.0	28.35	(2)	24.15	2,235	78.8	13.46	150.3	.00654																																																																																																																																																																																																										
5																																																																															do.	Same as No. 11	3	60	24.65	100	1,366	252	309	1,935	130.0	189.0	23.42	(2)	25.20	2,042	87.2	14.10	149.9	.00749																																																																																																																																																																																						
6																																																																																																			Sitka spruce.	3	60	24.65	150	2,049	339	388	2,390	142.0	241.5	23.42	(2)	25.20	1,980	84.5	12.92	157.3	.00670																																																																																																																																																																			
7																																																																																																																						do.	3	60	24.65	200	2,732	447	512	2,715	165.0	258.0	23.42	(2)	25.20	2,106	88.4	11.90	164.8	.00664																																																																																																																																																
8																																																																																																																																									do.	3	60	24.65	250	3,415	539	617	2,800	192.2	270.0	23.42	(2)	25.20	2,072	89.9	12.60	168.4	.00640																																																																																																																													
9																																																																																																																																																												do.	Same as No. 6	3	60	24.65	200	2,732	348	406	1,892	183.7	237.0	23.58	(2)	26.62	1,595	67.6	14.65	123.8	.00516																																																																																																									
10																																																																																																																																																																																do.	Same surface.	3	60	24.65	172	2,350	340	415	1,291	263.0	151.0	23.58	(2)	26.62	1,715	72.8	7.78	164.9	.00586																																																																																					
11																																																																																																																																																																																																				do.	Same as No. 49	2	40	16.40	225	3,073	267	314	3,130	85.3	277.0	24.77	(2)	24.20	2,260	91.3	8.56	116.0	.00530																																																																	
12																																																																																																																																																																																																																								do.	Same surface.	2	60	24.65	225	3,073	336	389	4,550	73.9	403.0	24.77	(2)	24.20	2,260	91.3	17.80	103.6	.00444																																													
13																																																																																																																																																																																																																																												do.	do.	2	80	32.80	225	3,073	430	490	6,130	70.2	571.0	24.77	(2)	24.20	2,145	86.6	16.30	117.5	.00426																									
14																																																																																																																																																																																																																																																																do.	do.	2	100	41.00	225	3,073	480	549	7,690	62.5	675.0	24.77	(2)	24.20	2,278	92.0	19.96	110.7	.00381					
15																																																																																																																																																																																																																																																																																				do.	do.	2	100	41.00
16	do.	do.	2	100	41.00	225	3,073	480	549	7,690	62.5	675.0	24.77	(2)	24.20	2,278	92.0	19.96	110.7	.00381																																																																																																																																																																																																																																																																				
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31	do.	do.	2	100	41.00	225	3,073	480	549	7,690	62.5	675.0	24.77	(2)	24.20	2,278	92.0	19.96	110.7	.00381																																																																																																																																																																																																																																																																				
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45																																																																																																																																																																																																																																																																																				do.	do.	2	100	41.00
46	do.	do.	2	100	41.00	2																																																																																																																																																																																																																																																																																		

¹ For conditions of cooking see Table 32.² Split wood.³ For runs 15 to 17, inclusive, see runs on "Mixtures of woods."

Run No.	Preliminary treatment of wood.	Stone.		Number of pockets used.	Pressure on 14-inch cylinder.	Pressure per square inch of pocket area.	Revolutions per minute.	Peripheral speed.	Average horsepower to grinder.	Maximum horsepower to grinder.	Bone-dry pulp in 24 hours.	Horsepower per ton bone-dry pulp in 24 hours.	Solid ground in 24 hours.	Weight per cubic foot bone-dry wood.	Average diameter of wood.	Moisture in wood.	Bone-dry pulp per 100 cubic feet solid ground.	Efficiency of conversion.	Screens per 100 cubic feet solid ground.	Average temperature of grinding.	Horsepower divided by pressure X speed.
		Kind of burr.	Surface.		Lbs. per sq. in.	Lbs.															
21		(Straight, cut 3 to 12 to inch.		3	40 50 20.5	16.4	175	2,445	368	470	4,380	96.8								161.0	
21		do.		3	50	20.5	175	2,445	400	451	4,352	92.3								167.4	
21		do.		3	50	20.5	175	2,445	403	457	4,503	88.5								179.3	
21		do.		3	50	20.5	175	2,445	406	442	4,445	91.4								167.0	
		Weighted averages.		3	50	20.5	175	2,445	400		4,500	90.0		32.38		24.41	2,648	81.9		174.6	
2		(Straight, cut 3 to 12 to inch.	Same as for No. 7 Montana lodge pole pine.	3	20	8.2	175	2,428	188	219	1,046	179.8	90.6	32.22	54	26.22	2,305	71.5	11.65	178.7	0.00944
3		do.	Same surface.	3	40	16.4	175	2,428	332	377	3,725	89.1	286.0	32.22	57	26.22	2,606	80.9	11.49	161.2	.00834
4		do.	do.	3	60	24.65	175	2,428	456	514	5,905	77.3	460.0	32.22	57	26.22	2,570	79.7	14.20	161.2	.00761
5		do.	do.	3	20	8.2	225	3,122	259	261	1,660	138.0	125.9	33.52	57	29.18	2,640	78.8	10.94	171.0	.00894
6		do.	do.	3	40	16.4	225	3,122	410	434	4,930	83.2	355.0	33.52	57	29.18	2,780	82.9	10.77	151.7	.00800
7		do.	do.	3	60	24.65	225	3,122	580	656	8,265	70.1	608.0	33.52	57	29.18	2,720	81.1	12.47	147.6	.00753
8		Diamond point, 6 to inch.	Stone dressed.	3	20	8.4	175	2,428	145	171				32.25	57	27.20				142.7	.00728
9		do.	Same surface.	3	60	24.65	175	2,428	492	485	1,542	273.0		32.25	57	27.20				174.0	.00705
10		do.	do.	3	60	24.65	250	3,470	592	621	1,880	315.0	200.0	32.25	57	27.20	1,880	58.3		151.0	.00691
11		(Straight, cut 3 to 12 to inch.	Same as for No. 2 western yellow pine.	3	40	16.4	200	2,762	334	384	6,215	53.7	505.0	32.25	67	27.20	2,460	76.2	12.5	123.4	.00736
12	Steamed	do.	Same surface.	3	40	16.4	200	2,762	306	356	4,470	68.5	359.0	32.25	57	27.20	2,490	77.1	11.8	133.4	.00675
13	do.	do.	do.	3	40	16.4	200	2,762	340	391	5,000	68.0	348.0	33.37	57	29.56	2,873	86.1	15.4	136.1	.00750
14	do.	do.	do.	3	40	16.4	200	2,762	337	387	5,510	63.0	404.0	32.78	67	28.88	2,730	83.4	9.51	133.0	.00763
15	do.	do.	do.	3	40	16.4	200	2,762	330	393	4,455	71.0	340.0	32.78	67	28.88	2,620	80.0	14.46	149.8	.00727

2 Commercial.

1 For conditions of cooking see Table 32.

TABLE 17.—Grinder run on tamarack—Continued.

Run No.	Stone.		Number of pockets used.	Pressure on 14-inch cylinder.	Pressure per square inch of pocket area.	Revolutions per minute.	Peripheral speed.	Average horsepower to grinder.	Maximum horsepower to grinder.	Bone-dry pulp in 24 hours.	Horsepower per ton bone-dry pulp in 24 hours.	Solid ground in 24 hours.	Weight per cubic foot bone-dry wood.	Average diameter of wood.	Moisture in wood.		Bone-dry pulp per 100 cubic feet solid rossed wood.	Efficiency of conversion.	Screenings per 100 cubic feet solid rossed wood.	Average temperature of grinding.	Horsepower divided by pressure $\times$ speed.	
	Kind of burr.	Surface.													P. ct.	Lbs.						
16	Steamed...	Kind of burr.	Same surface...	3	Lbs. per sq. in.	Lbs.	200	2,762	314	Tons.	89.5	266.0	32.78	5 $\frac{1}{2}$	28.88	2,638	80.5	16.70	150.2	0.00692		
17	do.....			do.....	3	40	16.4	200	2,762	330	397	3,475	95.0	277.0	29.70	5 $\frac{1}{2}$	33.01	2,515	84.6	11.88	163.0	.00728
18	do.....			do.....	3	40	16.4	200	2,762	338	389	3,240	104.3	261.0	29.70	6	33.01	2,452	83.6	10.99	156.3	.00745
19	do.....			do.....	3	40	16.4	200	2,762	288	356	2,950	97.6	233.5	33.70	5	27.93	2,524	74.9	16.90	143.4	.00655
20	do.....			do.....	3	40	16.4	200	2,762	326	378	3,850	62.8	380.0	33.70	5	27.93	2,730	81.0	12.86	125.4	.00719
21	do.....			do.....	3	40	16.4	200	2,762	314	370	3,850	81.5	308.0	32.36	6	28.04	2,500	77.3	16.40	141.8	.00692
22	do.....			do.....	3	40	16.4	200	2,762	295	349	3,035	97.2	274.0	32.36	6	28.04	2,218	68.5	11.60	143.6	.00650
23	do.....			do.....	3	40	16.4	200	2,762	291	361	3,480	83.7	309.0	32.36	5	28.04	2,250	69.5	16.90	132.0	.00647
24	do.....			do.....	3	40	16.4	200	2,762	348	435	5,050	68.9	378.0	32.36	5	28.04	2,670	82.5	8.35	139.1	.00766
25	do.....			do.....	3	40	16.4	200	2,762	302	354	3,000	100.6	250.0	34.25	5	25.32	2,398	70.0	16.88	141.5	.00661
26	do.....	do.....	3	30	12.3	225	3,085	302	343	1,898	159.2	144.8	33.29	5 $\frac{1}{2}$	22.51	2,620	78.7	8.14	187.2	.00795		
27	Steamed...	Kind of burr.	Same as No. 6 California lodgepole.	2	40	16.4	250	3,427	288	4,780	60.3	384.0	31.47	5 $\frac{1}{2}$	25.58	2,490	79.0	16.10	103.6	.00512		
28	do.....			do.....	2	55	22.55	201	2,760	283	311	4,420	64.0	366.0	31.47	5	25.58	2,412	76.5	18.42	113.0	.00455
29	do.....			do.....	2	70	28.7	179	2,458	280	310	4,350	64.4	368.0	31.47	5	25.58	2,360	75.0	22.30	117.8	.00397
30	do.....			do.....	2	85	34.8	158	2,165	289	322	3,912	73.9	330.0	31.47	5	25.58	2,365	75.1	28.65	108.3	.00383
31	do.....			do.....	2	100	41.0	136	1,868	278	311	3,840	72.4	314.0	31.47	6	25.58	2,442	77.6	30.35	113.0	.00364
32	do.....			do.....	2	40	16.4	225	3,081	258	288	2,865	90.0	252	31.68	5 $\frac{1}{2}$	24.54	2,275	71.7	9.70	127.1	.00510
33	do.....			do.....	2	60	24.65	225	3,081	360	408	4,270	84.3	363.0	31.68	5 $\frac{1}{2}$	24.54	2,350	74.1	22.20	136.5	.00473
34	do.....			do.....	2	80	32.8	225	3,081	421	482	4,790	88.0	410.0	31.68	5 $\frac{1}{2}$	24.54	2,338	73.6	36.70	128.5	.00417
35	Boiled...			do.....	2	40	16.4	225	3,081	272	300	2,530	107.6	206.5	31.68	6	24.54	2,450	77.3	15.47	134.7	.00538
36	do.....			do.....	2	60	24.65	225	3,081	382	420	4,670	81.9	381.0	31.68	6	24.54	2,450	77.3	18.30	142.5	.00502
37	do.....	do.....	2	80	32.8	225	3,081	438	499	4,565	95.8	385.0	31.47	6	25.58	2,370	75.3	28.70	130.6	.00433		

38	Steamed...	do.	3	40	16.4	200	2,740	360	390	2,950	122.0	222.0	31.68	61	24.54	2,600	83.9	9.66	141.2	.00801
39	do.	do.	3	40	16.4	225	3,081	262	281	2,050	127.9	185.8	31.68	48	24.54	2,208	68.6	17.60	142.3	.00518
40	do.	do.	3	60	24.65	225	3,081	351	335	3,795	92.5	330.0	31.68	48	24.54	2,300	72.5	15.50	135.7	.00461
41	do.	do.	3	80	32.8	225	3,081	429	465	4,455	96.1	390.0	31.68	53	24.54	2,290	72.3	18.40	129.8	.00454
42	Boiled...	Straight, cut 8 to inch.	3	40	16.4	225	3,080	224	280	1,675	133.8	164.0	30.72	53	24.47	2,042	66.6	13.28	148.3	.00444
43	do.	do.	3	60	24.65	225	3,080	299	336	2,745	109.0	240.0	30.72	53	24.47	2,285	74.5	15.07	133.4	.00394
44	do.	do.	3	80	32.8	225	3,080	360	410	3,495	103.0	316.0	30.72	53	24.47	2,210	72.0	21.00	127.6	.00356
45	do.	do.	3	60	24.65	225	3,080	308	346	2,975	103.7	274.0	30.40	53	25.75	2,168	71.4	20.27	125.9	.00405
46	Boiled in s a l t brine.	do.	3	60	24.65	225	3,080	312	337	3,265	95.5	264.5	33.14	53	24.34	2,465	74.5	14.36	136.9	.00410
47	Steamed...	Straight, cut 3 to inch; spiral, cut 12 to inch.	3	60	24.65	200	2,732	422	471	1,459	290.0	138.0	32.75	6	23.62	2,280	69.6	10.79	177.3	.00626
48	do.	do.	3	60	24.65	200	2,732	366	440	4,610	79.4	394.0	32.75	51	23.62	2,338	71.4	24.9	108.3	.00543
49	do.	do.	3	60	24.65	150	2,049	352	406	5,400	65.2	426.0	32.75	58	23.62	2,535	77.4	11.09	109.0	.00506
150	do.	do.	3	60	24.65	151	2,049	352	406	5,400	65.2	426.0	32.75	58	23.62	2,535	77.4	11.09	109.0	.00506
151	do.	do.	3	60	24.65	151	2,049	352	406	5,400	65.2	426.0	32.75	58	23.62	2,535	77.4	11.09	109.0	.00506
152	do.	do.	3	60	24.65	151	2,049	352	406	5,400	65.2	426.0	32.75	58	23.62	2,535	77.4	11.09	109.0	.00506
53	Spiral, cut 8 to inch; straight, cut 10 to inch.	do.	3	40	16.4	225	3,069	430	505	4,510	93.4	324.0	32.44	53	25.25	2,780	85.6	10.10	170.0	.00854
154	do.	do.	3	40	16.4	225	3,069	430	505	4,510	93.4	324.0	32.44	53	25.25	2,780	85.6	10.10	170.0	.00854
55	Steamed...	Spiral, aut 8 to inch; straight, cut 10 to inch.	3	30	12.3	250	3,387	286	325	2,615	109.5	233.0	31.21	52	25.20	2,245	72.0	13.50	144.0	.00886
56	do.	do.	3	35	14.3	221	2,990	288	332	2,755	104.5	234.0	31.21	52	25.20	2,330	75.2	13.65	134.0	.00674
57	do.	do.	3	40	16.4	196	2,638	290	348	2,735	106.3	240.0	31.21	52	25.20	2,275	72.8	14.40	130.0	.00605
58	do.	do.	3	45	18.4	167	2,262	285	329	2,535	112.5	220.0	31.21	52	25.20	2,305	73.9	12.60	149.0	.00684
59	do.	do.	3	50	20.5	154	2,086	290	329	2,420	120.0	210.0	31.21	52	25.20	2,300	73.6	9.50	153.0	.00677
60	do.	do.	3	55	22.5	153	2,075	286	333	2,500	114.3	220.0	31.21	52	25.20	2,270	72.7	16.20	146.0	.00612
61	do.	do.	3	60	24.65	140	1,898	286	323	2,165	132.0	198.0	31.21	52	25.20	2,186	70.1	11.50	135.0	.00611
62	do.	do.	2	40	16.4	250	3,387	269	312	3,315	81.2	298.0	31.21	51	25.20	2,222	71.2	12.95	139.0	.00641
63	do.	do.	2	45	18.4	232	3,143	267	316	3,390	78.8	294.0	31.21	51	25.20	2,305	73.9	9.65	145.0	.00436
64	do.	do.	2	50	20.5	225	3,049	273	324	3,385	80.6	288.0	31.21	51	25.20	2,340	75.0	11.25	139.0	.00461
65	do.	do.	2	55	22.5	220	2,980	272	330	3,080	88.3	266.0	31.21	51	25.20	2,320	74.3	10.50	146.0	.00405
66	do.	do.	2	60	24.65	201	2,722	272	335	2,880	94.5	247.0	31.21	51	25.20	2,330	74.6	14.15	142.0	.00405
67	do.	do.	2	65	26.6	213	2,882	274	342	2,670	102.8	232.0	31.21	51	25.20	2,302	73.8	12.30	141.0	.00387
68	do.	do.	2	70	28.7	190	2,575	272	351	2,745	99.1	223.0	31.21	51	25.20	2,350	75.3	11.95	141.0	.00387
69	do.	do.	2	60	24.65	225	3,049	334	380	5,010	66.6	458.0	32.46	51	28.64	2,190	67.5	19.70	136.0	.00444
70	do.	do.	2	60	24.65	222	3,008	333	382	4,710	70.7	434.0	32.46	52	28.64	2,175	67.0	21.90	135.0	.00448
71	do.	do.	2	60	24.65	218	2,958	335	384	4,605	72.7	460.0	32.46	52	28.64	2,000	61.6	19.40	137.0	.00460

1 See runs on mixed woods.

TABLE 17.—Grinder runs on tamarack—Continued.

Run No.	Stone.		Number of pockets used.	Pressure on 14-inch cylinder.	Pressure per square inch of pocket area.	Revolutions per minute.	Peripheral speed.	Average horsepower to grinder.	Maximum horsepower to grinder.	Bone-dry pulp in 24 hours.	Horsepower per ton bone-dry pulp in 24 hours.	Solid trossed wood ground in 24 hours.	Weight per cubic foot bone-dry wood.	Average diameter of wood.	Moisture in wood.		Bone-dry pulp per 100 cubic feet solid trossed wood.	Efficiency of conversion.	Screens per 100 cubic feet solid trossed wood bone-dry.	Average temperature of grinding.	Horsepower divided by pressure X speed.
	Preliminary treatment of wood.	Kind of burr.													P. ct.	Lbs.					
72	Steamed..	Diamond point, 6 to inch.	Same surface....	2	60	24.65	220	2,981	335	399	4.370	76.7	386.0	32.46	5 $\frac{1}{2}$	28.64	2,260	69.6	27.20	133.0	0.00456
73	do.....	do.....	do.....	2	60	24.65	217	2,941	336	398	4.050	73.9	374.0	32.46	5 $\frac{3}{4}$	28.64	2,435	75.0	27.30	137.0	.00463
74	do.....	do.....	do.....	2	60	24.65	205	2,780	333	391	4.490	74.2	360.0	32.46	5 $\frac{1}{2}$	28.64	2,490	76.7	23.30	137.0	.00486
75	do.....	do.....	do.....	2	60	24.65	197	2,673	335	388	4.775	70.1	372.0	32.46	4 $\frac{3}{4}$	28.64	2,560	78.9	18.30	131.0	.00508
76	do.....	do.....	do.....	2	60	24.65	185	2,505	335	394	5.075	66.0	378.0	32.46	5	28.64	2,680	82.5	19.30	140.0	.00541
77	do.....	do.....	do.....	2	60	24.65	170	2,302	334	404	5.780	57.9	380.0	32.46	5 $\frac{1}{2}$	28.64	3,040	93.6	11.10	138.0	.00587
78	do.....	Spiral, cut 8 to inch, straight, cut 10 to inch.	Same as No. 12 black gum.	2	40	16.40	175	2,348	216	276	1.320	163.6	119.0	30.88	6	33.60	2,215	71.7	11.4	164.0	.00561
79	do.....	do.....	Same surface....	2	40	16.40	175	2,348	105	258	1.020	191.0	102.0	29.37	10 $\frac{1}{2}$	32.80	2,000	68.1	12.7	170.0	.00506
80	do.....	do.....	Stone dressed....	2	40	16.40	175	2,348	207	231	.560	370.0	63.0	30.88	8 $\frac{1}{2}$	33.60	1,770	57.4	8.8	174.0	.00538
81	do.....	do.....	Same surface....	2	40	16.40	175	2,348	202	245	.541	373.0	65.0	29.37	8 $\frac{1}{2}$	32.80	1,672	57.0	13.9	175.0	.00524

1 Wood for these runs partially decayed.

TABLE 18.—Grinder runs on western larch.

Run No.	Preliminary treatment of wood.	Stone.		Number of pockets used.	Pressure on 14-inch cylinder.	Pressure per square inch of pocket area.	Revolutions per minute.	Peripheral speed.	Average horsepower to grinder.	Maximum horsepower to grinder.	Bone-dry pulp in 24 hours.	Horsepower per ton bone-dry pulp in 24 hours.	Solid ground in 24 hours.	Weight per cubic foot bone-dry wood.	Average diameter of wood.	Moisture in wood.		Bone-dry pulp per 100 cubic feet solid ground.	Efficiency of conversion.	Screenings per 100 cubic feet solid ground.	Average temperature of bone-dry.	Horsepower divided by pressure $\times$ speed.
		Kind of burr.	Surface.													P. ct.	Lbs.					
1	Steamed..	Straight, cut 3 to 12 to inch.	Same as No. 8 Montana lodgepole.	3	40	16.4	200	2,762	321	374	2,730	117.6	282.0	30.12	7	37.64	1,937	64.3	14.40	157.7	0.00709	
2		do.....	Same as for No. 9 Montana lodgepole.	3	30	12.3	225	3,085	334	378	3,220	103.6	338.0	27.94	7½	34.87	1,902	68.1	6.70	168.7	.00880	
3		do.....	Stone dressed....	3	60	24.65	100	1,366	267	298	1,830	146.0	212.0	26.55	7	36.38	1,728	65.1	6.20	138.2	.00793	
4		do.....	Same surface....	3	30	12.3	225	3,073	304	329	1,340	227.0	150.8	26.55	7	36.38	1,778	67.0	6.54	151.3	.00805	
5		do.....	Same as No. 15 Sitka spruce.	3	60	24.65	225	3,073	508	595	2,725	186.3	329.0	26.55	7	36.38	1,657	62.4	7.27	166.5	.00670	
6		do.....	Same surface....	3	40	16.4	175	2,390	303	344	1,086	279.0	115.0	26.55	7	36.38	1,887	71.1	5.80	177.9	.00772	
7	Spiral, cut 8 to 10 to inch.	do.....	Same as 24 green balsam.	2	60	24.65	175	2,387	309	357	3,570	86.5	314.0	27.62	9½	40.28	2,270	82.1	12.85	149.0	.00525	
8		do.....	Same surface....	2	40	16.4	225	3,069	304	342	2,525	120.1	227.0	27.62	8½	40.28	2,223	80.5	10.40	157.0	.00605	
9		do.....	do.....	2	60	24.65	225	3,069	401	442	4,155	96.6	376.0	27.62	9½	40.28	2,213	80.0	4.70	153.0	.00530	
10		do.....	do.....	2	80	32.8	225	3,069	473	567	5,490	86.3	515.0	27.62	9½	40.28	2,125	77.0	12.35	142.0	.00470	
11		do.....	do.....	2	80	32.8	175	2,387	382	456	4,355	87.6	406.0	27.62	7½	40.28	2,142	77.5	9.90	146.0	.00487	
12		do.....	do.....	2	80	32.8	125	1,705	307	348	3,445	89.1	312.0	27.62	7½	40.28	2,206	79.9	10.90	154.0	.00549	

1 For conditions of cooking see Table 32.

TABLE 19.—Grinder runs on Montana lodgepole pine.¹

Run No.	Preliminary treatment of wood.	Stone.		Number of pockets used.	Pressure on 14-inch cylinder.	Pressure per square inch of pocket area.	Revolutions per minute.	Peripheral speed.	Average horsepower to grinder.	Maximum horsepower to grinder.	Bone-dry pulp in 24 hours.	Horsepower per ton of bone-dry pulp in 24 hours.	Solid ground in 24 hours.	Weight per cubic foot of bone-dry wood.	Average diameter of wood.	Moisture in wood.		Bone-dry pulp per 100 cubic feet solid rossed wood.	Efficiency of conversion.	Screenings per 100 cubic feet solid rossed wood.	Average temperature of grinding.	Horsepower divided by pressure X speed.
		Kind of burr.	Surface.													Lbs. per sq. in.	Lbs.					
1		Straight, cut 3 to inch; spiral, cut 12 to inch.	Same as for run No. 23 spruce.	3	40	16.4	175	2,442	337.0	383	2,710	124.3	247.8	27.20	6½	16.90	2,190	80.5	8.68	170.8	0.50840	
2		do.	Stone dressed	3	20	8.2	225	3,122	223.0	263	2,210	105.3	216.0	25.00	7	32.60	2,040	81.6	13.70	157.4	.00910	
3		do.	Same surface	3	40	16.4	225	3,122	412.0	453	5,040	69.4	553.0	25.00	6½	32.60	2,145	85.9	17.76	137.9	.00804	
4		do.	do.	3	60	24.65	225	3,122	574.0	660	8,965	64.0	930.0	25.00	7½	32.60	1,910	77.1	25.80	148.0	.00745	
5		do.	do.	3	20	8.2	175	2,428	183.6	208	1,700	108.0	159.6	26.10	6½	18.80	2,130	81.6	8.96	86.0	.00921	
6		do.	do.	3	40	16.4	175	2,428	341.5	382	3,530	96.7	343.0	26.10	6½	18.80	2,060	78.9	7.69	89.6	.00856	
7		do.	do.	3	60	24.65	175	2,428	482.5	545	5,465	88.2	511.0	26.10	6½	18.80	2,140	82.0	12.75	87.8	.00805	
8	Steamed	do.	Same as yellow pine No. 3.	3	40	16.4	200	2,762	289.0	339	2,795	103.3	288.0	26.48	6½	19.32	1,942	73.4	22.73	148.3	.00638	
9		do.	Same as for western yellow pine No. 4.	3	30	12.3	225	3,085	318.0	356	2,795	113.7	223.0	26.57	6½	13.67	2,500	94.2	13.40	171.0	.00837	
10		Straight, cut 3 to inch; spiral, cut 10 to inch.	Same as for western yellow pine run No. 7.	3	60	24.65	250	3,435	588.0	650	6,285	93.6	588.0	26.55	6½	15.22	2,135	80.4	11.66	150.9	.00695	
11		do.	do.	3	40	16.4	250	3,435	424.0	476	3,375	125.7	303.0	26.55	6½	15.22	2,223	83.9	10.12	165.3	.00752	
12		do.	do.	3	20	8.2	250	3,435	228.0	269	964	237.0	92.0	26.55	6½	15.22	2,093	78.8	6.84	176.8	.00810	
13	Boiled	Straight, cut 8 to inch.	Same as No. 46 tamarack.	2	40	16.4	225	3,080	231.0	269	1,635	141.1	187.8	23.95	6½	24.90	1,741	72.8	17.06	140.7	.00457	
14	do.	do.	Same surface.	2	60	24.65	225	3,080	320.0	356	2,500	128.0	270.0	23.95	6½	24.90	1,850	77.3	24.15	136.0	.00421	
15	do.	do.	do.	2	80	32.8	225	3,080	374.0	419	2,820	132.7	304.0	23.95	6½	24.90	1,850	77.3	20.50	129.9	.00370	
16		Straight, cut 3 to inch; spiral, cut 12 to inch.	Same as No. 209 spruce.	3	60	24.65	100	1,367	251.0	295	2,612	96.1	241.0	24.70	7	24.80	2,170	87.9	16.59	127.1	.00745	
17		do.	do.	3	60	24.65	150	2,046	375.0	428	3,670	102.2	334.0	24.70	7	24.80	2,195	88.9	13.59	124.4	.00741	
18		do.	do.	3	60	24.65	200	2,732	486.0	536	4,395	110.7	406.0	24.70	7	24.80	2,160	87.5	16.62	135.0	.00722	
19		do.	do.	3	60	24.65	250	3,415	599.0	676	5,650	106.0	530.0	24.70	6½	24.80	2,130	86.3	16.50	136.3	.00711	
20		Spiral, cut 8 to inch; straight, cut 10 to inch.	Same as No. 18 red fir.	2	40	16.4	225	3,069	263.0	308	2,040	129.0	195.0	23.40	6½	24.80	2,085	89.1	7.69	153.0	.00522	

21	do.....	2	60	24.65	225	3,069	360.0	409	2,655	135.7	256.0	23.40	6	24.80	2,073	88.5	8.61	160.8	.00475
22	do.....	2	80	32.8	225	3,069	441.0	513	4,340	101.8	423.0	23.40	6	24.80	2,050	87.6	8.01	144.4	.00439
23	do.....	2	100	41.0	225	3,069	510.0	596	5,390	94.9	515.0	23.40	6	24.80	2,090	89.4	10.91	150.0	.00405
24	do.....																		
25	Straight, cut 3 to inch; spiral, cut 12 to inch.	3	55	22.55	225	3,069	500.0	581	3,630	137.8	334.0	24.61	6	25.00	2,175	88.3	12.20	173.0	.00723
26	do.....																		

¹ For conditions of cooking see Table 32.

² See runs on mixtures of woods.

TABLE 20.—Grinder runs on *California lodgepole pine*.¹

Run No.	Preliminary treatment of wood.	Kind of burr.	Stone.	Number of pockets used.	Pressure on 14-inch cylinder.		Pressure per square inch of pocket area.	Revolutions per minute.	Peripheral speed.	Average horsepower to grinder.	Maximum horsepower to grinder.	Bone-dry pulp in 24 hours.	Horse-dry pulp in ton bone-dry pulp in 24 hours.	Solid ground in 24 hours.	Weight per cubic foot bone-dry wood.	Average diameter of wood.	Moisture in wood.		Bone-dry pulp per 100 cubic feet solid tressed wood.	Efficiency of conversion.	Screenings per 100 cubic feet solid tressed wood.	Average temperature of grinding.	Horsepower divided by pressure×speed.
					Lbs. per sq. in.	Lbs.											P. ct.	Lbs.					
1	Steamed	Straight, cut 3 to inch; spiral, cut 12 to inch.	Same as larch No. 1.	3	40	16.4	200	2,762	312	358	2,515	124.2	329.5	24.74	63	22.78	1,526	61.7	16.86	155.3	0.00689		
2		do.	Same as western hemlock No. 1.	3	30	12.3	225	3,085	326	364	2,370	137.6	227	25.38	(2)	11.00	2,082	82.2	11.30	172.1	.00359		
3		do.	Same as spruce No. 1.	2	80	32.8	225	3,085	513	555	4,930	104.0	524	23.58	(2)	28.04	1,882	79.9	23.44	157.7	.00506		
4		Spiral, cut 6 to inch	Same as spruce No. 191.	3	20	8.2	175	2,400	193	222	1,661	116.2	161	25.35	(2)	10.93	2,062	81.5	11.57	142.1	.00998		
5		do.	Same surface.	3	40	16.4	175	2,400	357	391	4,230	84.4	432	25.35	(2)	10.93	1,960	77.4	15.90	121.6	.00907		
6		do.	do.	3	60	24.65	175	2,400	474	505	7,261	66.2	761	25.35	(2)	10.93	1,880	74.2	17.67	108.1	.00800		
7		Straight, cut 3 to inch; diamond point, 10 to inch.	Stone dressed	3	20	8.2	225	3,081	228	264	1,475	154.6	164	25.35	(2)	10.93	1,800	71.0	7.99	144.5	.00902		
8		do.	Same surface.	3	40	16.4	225	3,081	392	444	3,245	121.0	344	25.35	(2)	10.93	1,886	74.4	7.95	149.2	.00775		
9		do.	do.	3	60	24.65	225	3,081	579	651	6,400	90.5	695	25.35	(2)	10.93	1,842	72.7	21.00	114.4	.00760		
10		Straight, cut 3 to inch; spiral, cut 12 to inch.	Stone dressed	3	60	24.65	100	1,866	264	323	1,140	232.0	124.4	22.29	(2)	22.33	1,832	82.2	12.49	132.7	.00784		
11		do.	Same surface.	3	60	24.65	150	2,049	374	430	1,745	214.0	196	22.29	(2)	22.33	1,776	79.5	12.22	161.1	.00740		
12		do.	do.	3	60	24.65	200	2,732	512	594	2,035	249.0	253	22.29	(2)	22.33	1,623	72.9	13.17	168.8	.00760		
13		do.	do.	3	60	24.65	250	3,415	540	630	2,595	208.0	294	22.29	(2)	22.33	1,763	72.9	13.40	164.8	.00641		
14		do.	Stone dressed	2	20	8.2	225	3,073	126	157	504	250.0	59	22.67	(2)	24.67	1,707	75.1	5.88	139.9	.00500		
15		do.	Same surface.	2	40	16.4	225	3,073	270	301	1,675	161.2	178	22.67	(2)	24.67	1,878	82.7	7.50	164.0	.00535		
16		do.	do.	2	60	24.65	225	3,073	358	402	2,675	134.0	296	22.67	(2)	24.67	1,810	79.8	6.97	149.7	.00473		
17		do.	do.	2	80	32.8	225	3,073	439	508	3,725	117.4	386	22.67	(2)	24.67	1,930	85.0	10.60	139.6	.00435		
18		do.	do.	2	100	41.0	225	3,073	577	655	4,975	116.0	531	22.67	(2)	24.67	1,872	82.5	6.87	151.5	.00458		
19		Spiral, cut 8 to inch; straight, cut 10 to inch.	Same as No. 23 lodgepole.	2	40	16.4	225	3,069	259	307	1,081	239.5	111	23.05	(2)	26.05	1,952	84.6	7.05	175.6	.00514		
20		do.	Same surface.	2	60	24.65	225	3,069	347	410	1,763	196.7	184	23.05	(2)	26.05	1,921	83.4	9.65	168.0	.00459		
21		do.	do.	2	80	32.8	225	3,069	409	465	2,925	139.6	303	23.05	(2)	26.05	1,932	83.8	10.15	165.1	.00405		

TABLE 21.—Grinder runs on western yellow pine.¹

Run No.	Preliminary treatment of wood.	Stone.		Number of pockets used.	Pressure on 14-inch cylinder.	Pressure per square inch of pocket area.	Revolutions per minute.	Peripheral speed.	Average horsepower to grinder.	Maximum horsepower to grinder.	Bone-dry pulp in 24 hours.	Horsepower per ton bone-dry pulp in 24 hours.	Solid ground in 24 hours.	Weight per cubic foot bone-dry wood.	Average diameter of wood.	Moisture in wood.		Bone-dry pulp per 100 cubic feet solid tressed wood.	Efficiency of conversion.	Screens per 100 cubic feet solid tressed wood bone-dry.	Average temperature of grinding.	Horsepower divided by pressure $\times$ speed.
		Kind of burr.	Surface.													P. ct.	Lbs.					
1	Steamed..	Straight, cut 3 to inch; spiral, cut 12 to inch.	Same as hemlock No. 53.	3	40	16.4	200	2,768	376	422	4.100	91.7	486.0	23.50	2 7/8	44.27	1,688	71.8	26.05	121.1	0.00828	
2	Boiled....	do.	Same as hemlock No. 54.	3	40	16.4	200	2,762	307	356	4.020	76.4	368.0	23.65	2 8/16	54.54	2,182	92.3	26.05	124.7	.00677	
3	Steamed..	do.	Stone dressed....	3	40	16.4	200	2,762	326	394	4.400	74.1	392.0	28.24	10	43.83	2,243	79.2	34.10	129.2	.00719	
4	do.	do.	Same as spruce No. 151.	3	30	12.3	225	3,085	337	386	3.255	103.7	313.0	25.11	9	16.53	2,080	82.9	10.78	166.0	.00888	
5	do.	do.	Stone dressed....	3	60	24.65	250	3,435	580	661	6.620	87.6	610.0	26.55	9 1/2	24.15	2,170	81.8	15.42	157.5	.00685	
6	do.	do.	Same surface....	3	40	16.4	250	3,435	466	511	4.850	96.0	436.0	26.55	10	24.15	2,222	83.8	8.54	156.9	.00829	
7	do.	do.	do.	2	80	32.8	150	2,056	356	393	5.100	69.8	489.0	26.55	9 1/2	24.15	2,085	78.5	27.60	134.1	.00528	
8	Boiled....	Straight, cut 8 to inch.	Same as No. 7	2	40	16.4	225	3,080	244	259	1.620	150.7	219.0	22.50	9 1/2	23.40	1,480	65.8	14.92	129.6	.00483	
9	do.	do.	Same surface....	2	60	24.65	225	3,080	317	341	2.865	110.7	326.0	22.50	9 1/2	23.40	1,757	78.0	26.20	109.4	.00417	
10	do.	do.	do.	2	80	32.8	225	3,080	370	401	3.075	120.2	384.0	22.50	8 1/2	23.40	1,603	71.4	39.60	116.5	.00366	
11	Steamed..	Straight, cut 3 to inch; spiral, cut 12 to inch.	Same as No. 10 western hemlock.	3	40	16.4	200	2,732	320	397	1.011	316.0	114.3	24.25	8 1/2	23.09	1,770	73.0	21.20	165.3	.00715	
12	do.	do.	Same as No. 19 lodgepole.	3	60	24.65	100	1,366	269	300	2.630	102.3	275.0	23.97	10 1/2	22.31	1,912	79.9	26.64	105.0	.00799	
13	do.	do.	Same surface....	3	60	24.65	150	2,049	403	437	2.912	138.2	301.0	23.97	8 1/2	22.31	1,936	80.9	27.65	122.4	.00796	
14	do.	do.	do.	3	60	24.65	200	2,732	529	580	3.777	140.0	392.0	23.97	9 1/2	22.31	1,930	80.6	24.07	123.9	.00784	
15	do.	do.	do.	3	60	24.65	250	3,415	654	726	4.860	134.6	501.0	23.97	9 1/2	22.31	1,940	81.0	17.60	117.1	.00776	
16	do.	do.	Stone dressed....	2	40	16.4	225	3,069	290	338	3.333	114.3	255.0	22.90	9 1/2	28.65	1,990	86.9	8.37	150.8	.00676	
17	do.	do.	Same surface....	2	60	24.65	225	3,069	410	470	2.479	121.2	479.0	22.90	9 1/2	28.65	2,105	92.0	12.68	143.0	.00541	
18	do.	do.	do.	2	80	32.8	225	3,069	434	496	3.695	65.9	616.0	22.90	9 1/2	28.65	2,140	93.4	12.69	143.8	.00431	
19	do.	do.	do.	2	100	41.0	225	3,069	513	577	8.150	62.9	739.0	22.90	9 1/2	28.65	2,065	90.2	22.30	125.6	.00407	
20	do.	do.	do.	2	80	32.8	225	3,069	513	577	8.150	62.9	739.0	22.90	9 1/2	28.65	2,065	90.2	22.30	125.6	.00407	
21	do.	do.	do.	2	80	32.8	225	3,069	513	577	8.150	62.9	739.0	22.90	9 1/2	28.65	2,065	90.2	22.30	125.6	.00407	
22	do.	do.	do.	2	80	32.8	225	3,069	513	577	8.150	62.9	739.0	22.90	9 1/2	28.65	2,065	90.2	22.30	125.6	.00407	
23	do.	do.	do.	2	80	32.8	225	3,069	513	577	8.150	62.9	739.0	22.90	9 1/2	28.65	2,065	90.2	22.30	125.6	.00407	
24	do.	do.	do.	2	80	32.8	225	3,069	513	577	8.150	62.9	739.0	22.90	9 1/2	28.65	2,065	90.2	22.30	125.6	.00407	

17	do	Stone dressed	3	40.0	16.4	173.0	2,370	29.0	3,834	75.5	143.0
17-1	do	Same as for No. 18-1	3	40.0	16.4	174.0	2,380	332.0	4,350	76.3	178.0
18	do	Stone dressed	3	50.0	20.5	204.0	2,800	497.5	6,910	59.0	143.0
18-1	do	do	3	50.0	20.5	205.0	2,800	414.0	6,360	65.0	193.0
19	do	do	3	30.0	12.3	152.5	2,100	201.0	2,045	98.3	149.0
20	do	do	3	30.0	12.3	205.0	2,800	313.0	5,320	58.8	178.0
20-1	do	Same as for No. 22	3	30.0	12.3	235.0	2,800	304.0	3,620	83.8	198.0
21	do	Same as for No. 20	3	30.0	12.3	174.0	2,380	209.5	4,810	56.0	172.0
22	do	Stone dressed	3	60.0	24.65	205.0	2,800	481.0	7,320	65.8	185.0
23	do	Same as for No. 18-1	3	40.0	16.4	205.0	2,800	249.0	4,110	84.9	206.0
24	Straight, cut 3 to inch; spiral, cut 12 to inch.	Same as for commercial No. 51, hemlock.	3	40.0	16.4	175.0	2,445	395.0	409	4,305	91.8
25	Steamed	Straight, cut 3 to inch; spiral, cut 12 to inch.	3	40.0	16.4	200.0	2,768	370.0	455	5,100	72.5
26	do	Same as No. 7 balsam.	3	40.0	16.4	200.0	2,762	331.0	376	2,990	110.8
27	do	Same as for spruce No. 152.	3	30.0	12.3	225.0	3,085	337.0	380	2,255	149.7
28	Boiled	Straight, cut 8 to inch.	2	40.0	16.4	225.0	3,080	243.0	272	1,646	147.8
29	do	do	2	60.0	24.65	225.0	3,080	323.0	338	2,650	122.0
30	do	Same surface.	2	80.0	32.8	225.0	3,080	363.0	411	3,095	117.3
31	do	Same as No. 10 western yellow pine.	2	60.0	24.65	225.0	3,080	322.0	352	2,650	121.4
32	Steamed	Straight, cut 3 to inch; spiral, cut 12 to inch.	3	60.0	24.65	200.0	2,732	449.0	516	1,830	245.0
33	do	Stone dressed	3	60.0	24.65	200.0	2,732	371.0	430	4,225	87.8
34	do	Same surface	3	60.0	24.65	155.0	2,118	357.0	462	5,390	66.3

For conditions of cooking see Table 32.

² Approximate.

TABLE 23.—Grinder runs on loblolly pine.¹

Run No.	Preliminary treatment of wood.	Stone.		Number of pockets used.	Pressure on 14-inch cylinder.	Pressure per square inch.	Revolutions per minute.	Peripheral speed.	Average horsepower to grinder.	Maximum horsepower to grinder.	Bone-dry pulp in 24 hours.	Horsepower per ton, bone-dry pulp in 24 hours.	Solid ground in 24 hours.	Weight per cubic foot, bone-dry wood.	Average diameter of wood.	Moisture in wood.	Bone pulp per 100 cubic feet, solid crossed wood.	Efficiency of conversion.	Screenings per 100 cubic feet, solid crossed wood, bone-dry.	Average temperature of grinding.	Horsepower divided by pressure $\times$ speed.
		Kind of burr.	Surface.																		
1		Fall-cut wood.	Stone dressed	2	Lbs. 40	Lbs. 16.40	175	Pt. per minute, 2,348	225	248	Tons. 2.430	92.5	Cu. ft. 204	Lbs. 28.56	Inches.	P. ct. 20.20	Lbs. 2,380	P. ct. 83.4	Lbs. 15.3	° F. 150	0.00584
2			Same surface.	2	60	24.65	175	2,348	314	367	3.830	81.7	337	28.56		20.20	2,280	79.9	12.5	136	.00541
3			Same surface.	2	80	32.80	175	2,348	368	419	3.195	115.0	260	28.56		20.20	2,460	86.2	14.1	156	.00478
4			Same surface.	2	60	24.65	175	2,348	318	350	2.455	129.5	196	28.56		20.20	2,500	87.6	15.5	156	.00549
5			do.	2	60	24.65	175	2,348	226	264	1.165	194.0	99	28.56		20.20	2,350	82.4	8.7	169	.00587
6			Stone dressed	2	60	24.65	100	1,342	209	250	2.225	93.8	179	28.56		20.20	2,490	87.3	12.4	150	.00631
7			Same surface.	2	60	24.65	150	2,013	286	332	3.140	94.2	247	28.56		20.20	2,540	89.0	13.2	147	.00597
8			do.	2	60	24.65	250	3,355	430	489	4.865	88.3	404	28.56		20.20	2,410	84.5	12.0	146	.00520
9	Steamed.		Same as No. 15.	2	80	32.80	225	3,020	397	465	3.400	116.9	343	28.56		20.20	1,990	69.8	19.4	145	.00401
10			Same as No. 18.	2	80	32.80	175	2,348	198	251	1.772	111.0	145	29.52		16.80	2,445	82.8	22.8	149	.00513
11			Same as No. 23.	2	60	24.65	302	3,305	302	362	3.305	91.3	262	29.52		16.80	2,520	85.4	22.7	149	.00521
12			Same as No. 24.	2	80	32.80	175	2,348	371	413	4.350	85.2	347	29.52		16.80	2,519	85.0	17.4	143	.00481
13			Same as No. 27, cut spruce.	2	20	8.20	200	2,774	129	150	1.800	71.6	123	29.52		16.80	2,930		17.7	129	.00568
14			Spring-cut wood.																		
15			Spiral, cut 3 to 10 to inch.	2	40	16.40	175	2,348	220	278	1.585	138.5	143	27.56		23.62	2,220	80.6	8.8	158	.00571
16			do.	2	60	24.65	175	2,348	307	367	2.490	123.3	214	27.56		23.62	2,320	84.2	14.9	157	.00530
17			Same surface.	2	80	32.80	175	2,348	366	437	3.375	108.5	280	27.56		23.62	2,415	87.6	14.4	146	.00475
18			Same as No. 8.	2	60	24.65	100	1,342	250	290	1.990	131.0	133	27.56		23.62	2,390	86.8	9.6	160	.00629
19			Same surface.	2	60	24.65	150	2,013	282	313	1.960	144.0	159	27.56		23.62	2,460	89.3	8.5	156	.00569
20			do.	2	60	24.65	200	2,684	352	426	1.945	181.0	169	27.56		23.62	2,300	83.5	9.9	170	.00531
21			do.	2	60	24.65	250	3,355	390	464	2.225	175.2	196	27.56		23.62	2,276	82.6	12.1	168	.00471
22			Same as No. 15.	2	60	24.65	225	3,020	244	318	2.015	121.0	202	27.56		23.62	2,000	72.6	15.4	142	.00446
23	Steamed.		Same surface.	2	80	32.80	225	3,020	333	372	2.000	119.0	276	27.56		23.62	2,025	73.5	13.5	139	.00416
24			do.	2	80	32.80	225	3,020	410	481	3.865	106.0	370	27.56		23.62	2,090	75.9	22.9	139	.00415

20	do.	Same as No. 19.	2	60	24.65	225	3,020	367	438	3,005	122.0	261	27.56	23.62	2,300	83.5	28.0	143	.00493
21	do.	Same surface.	2	60	24.65	225	3,020	419	475	3,690	113.3	310	27.56	23.62	2,380	86.4	11.7	146	.00563
22	do.	Same as No. 13,	2	60	24.65	175	2,348	290	327	4,225	68.8	368	27.89	25.19	2,300	82.5	17.6	129	.00501
		noble fir.																	
26	do.	Same as No. 25.	2	40	16.40	175	2,348	205	267	1,955	104.8	171	27.38	24.07	2,280	83.3	22.3	152	.00532
27	do.	Same as No. 26.	2	60	24.65	175	2,348	296	342	2,900	102.0	254	27.38	24.07	2,280	83.3	18.2	145	.00511
28	do.	Same as No. 27.	2	80	32.80	175	2,348	374	427	3,500	106.8	312	27.38	24.07	2,240	81.9	28.7	155	.00485

² No. 29 was run on a coarse-grit stone.

¹ For conditions of cooking see Table 32.

TABLE 24.—Grinder runs on white pine.¹

Run No.	Stone.		Number of pockets used.	Pressure on 14-inch cylinder.	Pressure per square inch of pocket area.	Revolutions per minute.	Peripheral speed.	Average horsepower to grinder.	Maximum horsepower to grinder.	Bone-dry pulp in 24 hours.	Horsepower per ton bone-dry pulp in 24 hours.	Solid rossed wood ground in 24 hours.	Weight per cubic foot bone-dry wood.	Average diameter of wood.	Moisture in wood.	Bone-dry pulp per 100 cubic feet solid rossed wood.	Efficiency of conversion.	Screenings per 100 cubic feet solid rossed wood bone-dry.	Average temperature of grinding.	Horsepower divided by pressure X speed.
	Preliminary treatment of wood.	Kind of burr.																		
				Lbs. per sq. in.	Lbs.		Ft. per minute.		Tons.		Cu. ft.	Lbs.		Inches.	P. ct.	Lbs.	P. ct.	Lbs.	° F.	
1	.....	Diamond point, 6 to inch.	Same as No. 26 white fir.	2	60 24.65	175	2,372	248	305	2.035	122.0	218	20.40	51	61.74	1,870	91.7	4.4	150	0.00638
2	.....	do.	Same surface.	2	80 32.8	175	2,372	347	391	3.427	101.0	373	20.40	51	61.74	1,840	90.2	8.8	139	.00594
3	.....	do.	do.	2	100 41.0	175	2,372	451	489	3.010	90.0	534	20.40	51	61.74	1,880	92.1	11.2	142	.00581
4	.....	do.	do.	2	100 41.0	175	2,372	527	586	6.800	76.9	742	20.40	51	61.74	1,850	90.7	10.0	133	.00543
5	.....	do.	do.	2	60 24.65	175	2,372	228	250	2.035	111.0	211	20.40	51	61.74	1,930	94.6	11.6	144	.00676
6	.....	do.	do.	2	60 24.65	150	2,033	329	362	3.175	103.7	350	20.40	51	61.74	1,812	89.0	7.6	146	.00656
7	.....	do.	do.	2	60 24.65	200	2,710	458	491	4.670	98.1	480	20.40	51	61.74	1,947	95.5	6.7	147	.00685
8	.....	do.	do.	2	60 24.65	250	3,388	496	536	5.200	95.5	532	20.40	51	61.74	1,952	95.8	6.7	145	.00594
9	Steamed.	do.	Same as No. 34 white fir.	2	40 16.4	225	3,049	302	354	2.330	123.7	318	20.10	51	57.20	1,470	73.1	9.8	153	.00604
10	do.	do.	Same surface.	2	60 24.65	225	3,049	400	456	3.600	111.0	489	20.10	51	57.20	1,470	73.1	15.4	153	.00531
11	do.	do.	do.	2	80 32.8	225	3,049	400	531	4.245	108.4	552	20.10	51	57.20	1,535	76.4	22.15	139	.00460
12	do.	do.	do.	2	100 41.0	225	3,049	517	573	4.675	110.7	669	20.10	51	57.20	1,400	69.6	30.6	138	.00414

¹ For conditions of steaming see Table 32.

TABLE 25.—Grinder runs on *Engelmann spruce* (Montana).¹

Run No.	Stone.		Number of pockets used.	Pressure on 14-inch cylinder.	Pressure per square inch of pocket area.	Revolutions per minute.	Peripheral speed.	Average horsepower to grinder.	Maximum horsepower to grinder.	Bone-dry pulp in 24 hours.	Horsepower per ton bone-dry pulp in 24 hours.	Solid ground in 24 hours.	Weight per cubic foot bone-dry wood.	Average diameter of wood.	Moisture in wood.		Bone-dry pulp per 100 cubic feet solid ground wood.	Efficiency of conversion.	Screenings per 100 cubic feet solid ground wood bone-dry.	Average temperature of grinding.	Horsepower divided by pressure $\times$ speed.
	Preliminary treatment of wood.	Kind of burr.		Lbs. per sq. in.	Lbs.	100	Ft. per minute.	216	Tons.	24	79.1	Cu. ft.	Lbs.	Inches.	P. ct.	Lbs.	P. ct.	Lbs.	Lbs.	° F.	0.00346
1		Spiral, cut 12 to inch; straight, cut 3 to inch.	2	60	24.65	100	1,355	216	264	2.730	79.1	246	24.90	9 $\frac{1}{2}$	44.00	2,220	89.1	13.4	137	137	0.00346
2		do.	2	60	24.65	150	2,033	283	328	4.260	66.4	368	24.90	9	44.00	2,315	92.9	12.5	132	132	.00365
3		do.	2	60	24.65	200	2,710	381	446	5.840	67.6	486	24.90	8 $\frac{1}{2}$	44.00	2,315	92.9	16.4	129	129	.00370
4		do.	2	60	24.65	250	3,388	455	539	7.050	64.5	611	24.90	9 $\frac{1}{2}$	44.00	2,300	92.4	9.4	130	130	.00345
5		do.	2	60	16.40	225	3,049	281	333	3.895	76.1	328	24.90	9	44.00	2,253	90.5	4.2	135	135	.00066
6		do.	2	60	24.65	225	3,049	422	461	6.140	67.3	554	24.90	9	44.00	2,220	89.1	8.5	134	134	.00361
7		do.	2	80	32.80	225	3,049	484	534	9.280	52.2	770	24.90	8 $\frac{1}{2}$	44.00	2,413	96.8	4.2	133	133	.00066
8	Steamed.	do.	2	60	16.40	175	2,371	203	233	2.580	78.7	252	24.90	10 $\frac{1}{2}$	44.00	2,050	82.4	20.2	122	122	.00322
9		do.	2	60	24.65	175	2,371	278	332	3.500	79.5	328	24.90	10	44.00	2,130	85.5	48.2	114	114	.00175
10		do.	2	80	32.80	175	2,371	326	378	4.565	71.3	476	24.90	8 $\frac{1}{2}$	44.00	1,915	76.9	104.0	113	113	.00420
11		do.	2	40	16.40	175	2,371	240	278	3.645	65.9	302	24.90	9 $\frac{1}{2}$	44.00	2,405	96.6	9.7	132	132	.00365
12		do.	2	60	24.65	175	2,371	330	365	5.655	58.5	494	24.90	9 $\frac{1}{2}$	44.00	2,290	92.0	19.1	128	128	.00365
13		do.	2	80	32.80	175	2,371	399	450	6.880	58.0	651	24.90	10	44.00	2,110	84.8	26.5	120	120	.00314
14		Spiral, cut 8 to inch; straight, cut 10 to inch.	2	40	16.40	175	2,348	204	228	2.370	86.0	222	23.86	8	46.79	2,140	89.7	4.5	137	137	.00330
15		do.	2	60	24.65	175	2,348	294	331	4.000	73.5	360	23.86	8	46.79	2,220	93.1	10.7	130	130	.00337
16		do.	2	80	32.80	175	2,348	313	354	4.840	64.6	402	23.86	8 $\frac{1}{2}$	46.79	2,405	10.08	12.9	131	131	.00406
17		do.	2	60	21.65	100	1,392	187	201	2.525	74.0	223	23.86	10	46.79	2,275	95.4	11.3	136	136	.00364
18		do.	2	60	21.65	150	2,013	259	303	3.580	76.6	306	23.86	7 $\frac{1}{2}$	46.79	2,215	92.9	7.8	136	136	.00322
19		do.	2	60	24.65	200	2,684	333	370	4.880	68.3	437	23.86	7 $\frac{1}{2}$	46.79	2,230	93.5	4.3	131	131	.00503

¹ For conditions of cooking see Table 32.

TABLE 26.—Grinder runs on *Engelmann spruce* (Colorado).¹

Run No.	Preliminary treatment of wood.	Stone.		Number of pockets used.	Pressure on 14-inch cylinder.	Pressure per square inch of pocket area.	Revolutions per minute.	Peripheral speed.	Average horsepower to grinder.	Maximum horsepower to grinder.	Bone-dry pulp in 24 hours.	Horsepower per ton bone-dry pulp in 24 hours.	Solid ground in 24 hours.	Weight per cubic foot bone-dry wood.	Average diameter of wood.	Moisture in wood.	Bone-dry pulp per 100 cubic feet solid ground wood.	Efficiency of conversion.	Screenings per 100 cubic feet solid ground wood.	Average temperature of grinding.	Horsepower divided by pressure × speed.
		Kind of burr.	Surface.		Lbs. per sq. in.	Lbs.		Ft. per minute.			Tons.		Cu. ft.	Lbs.	Inches.	P. ct.	Lbs.	P. ct.	Ibs.	° F.	
1	.....	Spiral, cut 8 to 10 to inch.	Same as No. 54 tamarack.	2	40	16.4	225	3,069	299	348	2,700	110.8	272	20.48	5 1/2	59.20	1,980	96.5	12.35	140	0.00594
2	.....	do.	Same surface.	2	60	24.65	225	3,069	411	457	4,535	90.6	465	20.48	5 1/2	59.20	1,951	95.2	13.30	136	.00543
3	.....	do.	do.	2	80	32.8	225	3,069	478	538	5,600	85.4	577	20.48	5 1/2	50.20	1,940	94.6	16.20	150	.00475
4	.....	do.	Same as No. 3 white fir.	2	60	24.65	175	2,387	323	358	3,230	100.0	343	20.48	5 1/2	59.20	1,882	91.9	13.30	144	.00548
5	.....	do.	Same as No. 29 balsam.	3	60	24.65	100	1,355	257	300	3,325	77.3	310	22.22	6	57.30	2,150	96.7	11.10	137	.00769
6	.....	do.	Same surface.	3	60	24.65	150	2,033	383	444	4,735	80.9	457	22.22	6	57.30	2,073	93.2	10.80	133	.00765
7	.....	do.	do.	3	60	24.65	200	2,710	510	589	6,535	78.1	662	22.22	6	57.30	1,972	88.8	6.70	138	.00763
8	.....	do.	do.	3	60	24.65	250	3,388	560	665	7,380	76.1	760	22.22	6	57.30	1,940	87.3	6.60	132	.00670
9	.....	do.	Same as No. 7 white fir.	2	40	16.4	175	2,372	231	263	2,555	90.4	243	21.17	6	58.26	2,105	99.5	6.8	140	.00595
10	.....	do.	Same surface.	2	60	24.65	175	2,372	304	362	4,075	74.6	383	21.17	6	58.26	2,127	.....	8.9	136	.00520
11	.....	do.	do.	2	80	32.8	175	2,372	339	420	4,745	71.5	438	21.17	6	58.26	1,955	.....	11.4	131	.00436
12	.....	do.	do.	2	100	41.0	175	2,372	416	493	5,215	67.0	488	21.17	6	58.26	2,080	98.4	10.7	130	.00428
13	Steamed.	do.	do.	2	40	16.4	212	2,870	233	280	2,117	111.0	264	21.17	6	58.26	1,603	73.9	17.2	132	.00498
14	do.	do.	do.	2	60	24.65	223	3,020	308	377	3,100	97.4	334	21.17	6	58.26	1,890	89.4	13.2	132	.00413
15	do.	do.	do.	2	80	32.8	207	2,805	341	411	3,990	95.0	395	21.17	6	58.26	1,830	86.0	24.2	122	.00370
16	do.	do.	do.	2	100	41.0	207	2,805	414	490	4,325	91.4	525	21.17	6	58.26	1,792	81.5	23.8	129	.00356
17	do.	do.	do.	2	60	24.65	200	2,710	306	350	3,125	97.8	348	21.17	6	58.26	1,732	84.8	15.7	129	.00458
18	do.	do.	do.	2	60	24.65	195	2,642	307	372	3,500	86.3	375	21.17	6	58.26	1,900	89.8	15.3	126	.00470
19	do.	do.	Same as No. 35 white fir.	2	70	28.70	225	3,020	368	479	4,840	76.0	488	21.17	6	58.26	1,980	93.6	12.8	153	.00425

¹ For cooking conditions see Table 32.

For cooking conditions see Table 32.

Run No.	Stone.		Number of pockets used.	Pressure on 14-inch cylinder.	Pressure per square inch of pocket area.	Revolutions per minute.	Peripheral speed.	Average horsepower to grinder.	Maximum horsepower to grinder.	Bone-dry pulp in 24 hours.	Horsepower per ton bone-dry pulp in 24 hours.	Solid rossed wood ground in 24 hours.	Weight per cubic foot bone-dry wood.	Average diameter of wood.	Moisture in wood.		Bone-dry pulp per 100 cubic feet solid rossed wood.	Efficiency of conversion.	Screenings per 100 cubic feet solid rossed wood.	Average temperature of grinding.	Horsepower divided by pressure $\times$ speed.
	Kind of burr.	Surface.													P. ct.	Lbs.					
1		Same as for western larch No. 2.	3	Lbs. per sq. in. 30	Lbs. 12.3	225	Ft. per minute. 3,085	307	358	Tons. 2.225	Cu. ft. 137.8		Lbs. 25.38	Inches. (2)	P. ct. 16.66	Lbs. 2,075		P. ct. 81.8	Lbs. 12.88	174.2	0.00809
2		Stone dressed.	3	20	8.2	250	3,427	217	245	1,840	118.0	188.4	24.60	(2)	19.07	1,952		79.4	8.59	154.0	.00772
3		do.	3	40	16.4	250	3,427	368	407	4,550	81.0	435.0	24.60	(2)	19.07	2,095		84.3	13.87	145.3	.00654
4		do.	3	60	24.65	250	3,427	510	586	7,050	72.4	680.0	24.60	(2)	19.07	2,075		84.3	13.48	136.3	.00602
5		Boiled.	2	40	16.4	225	3,080	197	245	1,500	131.2	164.0	23.60	(2)	24.00	1,836		77.5	20.30	107.0	.00890
6		do.	2	60	24.65	225	3,080	256	329	1,985	129.0	234.0	23.60	(2)	24.00	1,698		71.9	36.00	109.0	.00837
7		do.	2	80	32.8	225	3,080	331	404	2,920	113.3	333.0	23.60	(2)	24.00	1,750		85.7	44.20	103.1	.00828
8		Stone dressed	3	60	24.65	100	1,366	263	313	2,095	125.7	208.0	23.60	(2)	22.60	2,003		85.7	14.37	134.9	.00750
9		Same surface.	3	60	24.65	150	2,049	346	401	3,107	111.2	296.0	23.40	(2)	22.60	2,100		89.7	13.51	147.2	.00885
10		do.	3	60	24.65	200	2,732	468	505	4,340	108.0	407.0	23.40	(2)	22.60	2,130		91.0	16.70	144.0	.00945
11		do.	3	60	24.65	250	3,415	560	651	5,340	105.0	494.0	23.40	(2)	22.60	2,160		92.3	13.17	142.9	.00865
12		do.	2	40	16.4	225	3,073	222	280	1,047	212.0	104.0	23.00	(2)	22.60	2,008		87.4	12.70	155.8	.00440
13		Same surface.	2	80	24.65	225	3,073	313	414	2,005	156.0	200.0	23.00	(2)	22.60	2,000		87.0	10.60	155.0	.00413
14		do.	2	80	32.8	225	3,073	409	513	2,917	140.2	292.0	23.00	(2)	22.60	1,992		86.6	20.70	149.3	.00405
15		do.	2	100	41.0	225	3,073	483	615	3,065	144.0	310.0	23.00	(2)	22.60	1,945		84.3	16.29	134.3	.00644
16		Same as No. 47	3	60	24.65	200	2,732	414	493	1,107	374.0	126.7	23.00	(2)	22.60	1,750		76.1	28.83	178.4	.00614
17		do.	3	60	24.65	200	2,732	382	454	1,592	240.0	197.0	23.00	(2)	22.60	1,618		70.3	31.27	188.3	.00586
18		do.	3	60	24.65	189	2,580	368	432	1,920	400.0	94.2	23.00	(2)	22.60	1,952		81.9	18.30	176.7	.00578
19		do.	2	80	32.8	225	3,069	458	541	4,495	102.0	435.0	23.00	(2)	22.60	2,005		89.9	32.50	166.0	.00455

TABLE 28.—Grinder runs on white birch.¹

Run No.	Preliminary treatment of wood.	Stone.		Number of pockets used.	Pressure on 14-inch cylinder.	Pressure per square inch of pocket area.	Revolutions per minute.	Peripheral speed.	Average horsepower to grinder.	Maximum horsepower to grinder.	Bone-dry pulp in 24 hours.	Horsepower per ton bone-dry pulp in 24 hours.	Solid rossi wood ground in 24 hours.	Weight per cubic foot bone-dry wood.	Average diameter of wood.	Moisture in wood.	Bone-dry pulp per 100 cubic feet solid rossi wood.	Efficiency of conversion.	Screens per 100 cubic feet solid rossi wood bone-dry.	Average temperature of grinding.	Horsepower divided by pressure X speed.
		Kind of burr.	Surface.		Lbs. per sq. in.	Lbs.		Ft. per minute.			Tons.	Cu. ft.	Lbs.	Inches.	P. ct.	Lbs.	P. ct.	Lbs.		° F.	0.00505
1	Steamed...	Straight, cut 3 to inch; spiral, cut 12 to inch.	Same as for tamarack No. 25.	3	40	16.4	200	2,762	229.0	285	3.455	66.3	265.0	36.37	5½	39.23	2,580	71.0	6.70	126.9	0.00505
2	.....	.....do.....	Same as for red fir No. 4.	3	30	12.3	225	3,085	338.0	370	2.980	113.2	200.0	34.62	8½	37.34	2,980	86.0	6.51	176.0	.00890
3	Boiled....	Straight, cut 8 to inch.	Same as poplar No. 5.	2	40	16.4	225	3,080	198.0	238	2.580	76.7	228.0	32.18	6½	38.60	2,286	71.1	11.57	110.0	.00392
4	do.....	do.....	Same surface....	2	60	24.65	225	3,080	286.0	352	4.013	71.2	322.0	32.18	6½	38.60	2,492	77.5	9.79	125.0	.00376
5	do.....	do.....	do.....	2	80	32.8	225	3,080	334.0	415	4.475	74.6	355.0	32.18	7½	38.60	2,520	78.4	12.60	130.6	.00331
6	do.....	Spiral, cut 8 to inch; straight, cut 10 to inch.	Same as for No. 21, California lodgepole.	2	40	16.4	100	1,364	138.8	150	.718	193.1	52.4	34.15	8	40.50	2,740	80.3	10.80	167.1	.00620
7	.....	.....do.....	Same surface....	2	60	24.65	100	1,364	191.0	222	1.218	157.0	85.4	34.15	8	40.50	2,855	83.6	4.61	163.6	.00568
8	.....	.....do.....	do.....	2	80	32.8	100	1,364	259.0	294	1.997	129.7	130.0	34.15	7	40.50	3,075	90.0	5.22	163.9	.00580
9	.....	.....do.....	do.....	2	100	41.0	100	1,364	287.0	322	2.550	112.6	163.3	34.15	8	40.50	3,120	91.5	8.01	161.2	.00513

¹ For cooking conditions see Table 32.

TABLE 29.—Grinder runs on aspen.¹

Run No.	Stone.		Number of pockets used.	Pressure on 14-inch cylinder.	Pressure per square inch of pocket area.	Revolutions per minute.	Peripheral speed.	Average horsepower to grinder.	Maximum horsepower to grinder.	Bone-dry pulp in 24 hours.	Horsepower per ton bone-dry pulp in 24 hours.	Solid tressed wood ground in 24 hours.	Weight per cubic foot bone-dry wood.	Average diameter of wood.	Moisture in wood.	Bone-dry pulp per 100 cubic feet solid tressed wood.	Efficiency of conversion.	Screenings per 100 cubic feet solid tressed wood bone-dry.	Average temperature of grinding.	Horsepower × speed by pressure.
	Kind of burr.	Surface.																		
1	Steamed...	Kind of burr.	Stone dressed...	3	Lbs. per sq. in.	200	Ft. per minute.	209.3	266	Tons.	63.4	Cu. ft.	Lbs.	Inches.	P. ct.	Lbs.	P. ct.	Lbs.	° F.	0.00461
2				3	40	225	2,762	209.3	374	2.340	139.0	210.0	26.61	61	51.95	1,870	75.2	6.13	133.3	
3	Boiled....			2	30	225	3,085	325.0	209	2.824	63.4	321.0	25.33	61	43.28	2,227	83.8	6.86	175.7	.00856
4	do.....			2	40	225	3,080	240.0	290	3.383	70.8	365.0	25.33	71	42.88	1,856	73.3	9.01	124.1	.00316
5	do.....			2	80	225	3,080	277.0	318	4.590	60.5	479.0	25.33	71	42.88	1,920	75.9	10.87	116.0	.00274
6	do.....			2	40	100	1,364	137.0	164	.438	313.0	40.7	24.00	51	46.70	2,150	89.6	3.26	171.1	.00612
7	do.....			2	60	100	1,364	198.0	220	.895	221.0	80.2	24.00	51	46.70	2,230	93.0	7.21	166.2	.00589
8	do.....			2	80	100	1,364	253.0	294	1.390	182.0	128.7	24.00	51	46.70	2,160	90.0	7.45	175.1	.00565
9	do.....			2	100	100	1,364	255.0	324	1.760	162.0	166.0	24.00	61	46.70	2,115	88.1	5.00	164.0	.00510
10	do.....			2	40	200	2,728	240.0	286	.565	426.0	55.7	24.00	61	46.70	2,027	84.5	5.69	187.3	.00336
11	do.....			2	60	200	2,728	306.0	367	1.030	297.0	98.5	24.00	61	46.70	2,090	87.1	6.92	180.3	.00455
12	do.....			2	80	200	2,728	508.0	573	2.200	231.0	200.0	24.00	61	46.70	2,200	91.6	6.22	176.5	.00568
13	do.....			2	100	200	2,728	475.0	535	2.745	173.0	246.0	24.00	7	46.70	2,222	92.6	6.18	170.1	.00424

¹ For cooking conditions see Table 32.

TABLE 30.—Grinder runs on black gum.¹

Run No.	Stone.		Number of pockets used.	Pressure on 14-inch cylinder.	Pressure per square inch of pocket area.	Revolutions per minute.	Peripheral speed.	Average horsepower to grinder.	Maximum horsepower to grinder.	Bone-dry pulp in 24 hours.	Horsepower per ton bone-dry pulp in 24 hours.	Solid rossed wood ground in 24 hours.	Weight per cubic foot bone-dry wood.	Average diameter of wood.	Moisture in wood.	Bone cubic feet solid rossed wood per 100 cubic feet solid rossed wood.	Efficiency of conversion.	Screenings per 100 cubic feet solid rossed wood bone-dry.	Average temperature of grinding.	Horsepower divided by pressure X speed.
	Preliminary treatment of wood.	Kind of burr.		Lbs. per sq. in.	Lbs.		Ft. per minute.			Tons.		Cu. ft.	Lbs.	Lbs.	P. ct.	Lbs.	P. ct.		° F.	
1	.....	Spiral, cut 8 to 10 to inch.	2	40	16.40	175	2,348	234	277	1.405	261.0	75	30.71	8	47.02	2,380	77.5	6.4	128	0.00607
2	.....	do.	2	60	24.65	175	2,348	322	370	2.075	229.0	106	30.71	84	47.02	2,640	86.0	7.8	116	.00555
3	.....	do.	2	80	32.80	175	2,348	421	465	2.975	141.7	225	30.71	84	47.02	2,640	86.0	6.3	158	.00548
4	.....	do.	2	60	24.65	100	1,342	220	253	1.287	171.0	100	30.71	84	47.02	2,965	83.6	2.7	168	.00664
5	.....	do.	2	60	24.65	150	2,013	287	315	1.655	173.3	128	30.71	84	47.02	2,985	84.2	4.2	167	.00579
6	.....	do.	2	60	24.65	200	2,684	376	422	2.080	181.0	159	30.71	84	47.02	2,620	85.4	1.9	170	.00568
7	.....	do.	2	60	24.65	250	3,355	422	466	2.465	171.0	193	30.71	74	47.02	2,555	83.1	2.6	175	.00510
8	.....	do.	2	60	24.65	200	2,684	395	444	5.305	74.4	392	30.71	74	47.02	2,710	88.2	2.1	139	.00595
9	Steamed.	do.	2	60	24.65	200	2,684	323	380	4.460	72.3	359	28.70	9	47.00	2,485	86.6	5.9	139	.00488
10	.....	do.	2	60	24.65	200	2,684	305	378	3.660	83.4	317	28.70	7	47.00	2,310	80.5	4.4	140	.00461
11	do.	do.	2	40	16.40	200	2,684	241	279	2.505	96.1	218	28.70	7	47.00	2,295	84.0	2.0	141	.00547
12	do.	do.	2	80	32.80	200	2,684	358	469	4.440	80.7	371	28.70	84	47.00	2,390	83.7	6.1	144	.00406
13	.....	do.	2	60	24.65	175	2,348	294	370	3.595	81.7	278	31.40	64	42.07	2,580	82.2	5.3	149	.00509
2 14	.....	Straight, cut 3 to 12 to inch.	2	20	8.20	200	2,774	137	186	1.950	70.8	158	31.40	7	42.07	2,460	78.3	20.1	130	.00603

¹ For conditions of cooking see Table 32.² No. 14 was run on a coarse grit stone.

Kind of wood.	Run No.	Stone.		Number of pockets used.	Pressure on 14-inch cylinder.	Pressure per square inch of pocket area.	Revolutions per minute.	Peripheral speed.	Average horsepower to grinder.	Maximum horsepower to grinder.	Bone-dry pulp in 24 hours.	Horse power per ton bone-dry pulp in 24 hours.	Solid ground in 24 hours.	Weight per cubic foot bone-dry wood.	Average diameter of wood.	Moisture in wood.		Bone-dry pulp per 100 cubic feet solid rossed wood.	Efficiency of conversion.	Screenings per 100 cubic feet solid rossed wood, bone-dry.	Average temperature of grinding.	Horsepower divided by pressure X speed.
		Kind of burr.	Surface.		Lbs. per sq. in.	Lbs.	Feet per minute.				Tons.		Cu. ft.	Lbs.	Inches.	P. ct.	Lbs.	P. ct.	Lbs.	P. ct.	°F.	
Hemlock-spruce.....	46-A	Straight, cut 3 to inch.	Same surface as run 45, 109-2.	3	50	20.5	175	2,450	392.0	465	4.275	91.7									152.5	0.00780
Hemlock.....	46-B	do.	do.	3	50	20.5	175	2,450	413.0	466	4.885	84.6									175.5	.00823
Spruce.....	46-C	do.	do.	3	50	20.5	175	2,450	407.0	466	4.878	83.5									160.0	.00810
Hemlock-Spruce.....	49-A	Straight, cut 3 to inch; spiral, cut 12 to inch.	Stone dressed.	3	40	16.4	175	2,445	360.4	427	4.880	73.8									155.0	.00899
Hemlock.....	49-B	Spiral, cut 12 to inch.	Same surface.	3	40	16.4	175	2,445	370.0	426	4.885	75.7									168.3	.00922
Jack pine-tamarack..	50	Spiral, cut 8 to inch; straight, cut 10 to inch.	Same as No. 221 spruce.	2	60	24.65	225	3,069	280.0	330	3.000	93.2	151	24.44	67	36.57	2,088	75.0	11.69	127.0		.00370
Do.....	51	Straight, cut 10 to inch.	Same as No. 50.	3	60	24.65	225	3,069	423.0	489	3.970	106.5	282	24.44	67	36.57	1,940	74.4	9.87	139.0		.00559
Do.....	52	do.	Same as No. 51.	3	60	24.65	225	3,069	400.0	469	3.940	101.4	132	24.44	67	36.57	2,150	77.3	11.78	142.8		.00529
Western yellow pine-Montana lodgepole pine.	20	Straight, cut 3 to inch; spiral, cut 12 to inch.	Same as No. 19; western yellow pine.	3	40	16.4	200	2,728	384.0	423	3.940	97.5	171	25.03	78	26.25	2,247	91.1	6.06	136.3		.00858
Do.....	21	Spiral, cut 12 to inch.	Same surface.	3	40	16.4	200	2,728	382.0	444	3.800	100.5	110	25.03	78	26.25	2,220	90.6	8.09	146.2		.00852
Do.....	22	do.	do.	3	40	16.4	200	2,728	368.0	416	3.535	104.0	208	25.03	8	26.25	2,230	89.6	8.68	146.9		.00822
Montana lodgepole pine-western larch.	23	do.	do.	3	40	16.4	200	2,728	355.0	413	3.307	107.2	109	25.03	83	26.25	2,200	86.4	3.89	149.4		.00793

Wood received no further treatment after barking prior to grinding on a medium-grit Lombard stone.

TABLE 31.—Runs on mixtures of woods—Continued.

Kind of wood.	Stone.		Run No.	Number of pockets used.	Pressure on 14-inch cylinder.	Pressure per square inch of pocket area.	Revolutions per minute.	Peripheral speed.		Average horsepower to grinder.	Maximum horsepower to grinder.	Bone-dry pulp in 24 hours.	Horsepower per ton bone-dry pulp in 24 hours.	Solid ground in 24 hours.	Weight per cubic foot bone-dry wood.	Average diameter of wood.	Moisture in wood.		Bone-dry pulp per 100 cubic feet of solid ground wood.	Efficiency of conversion.	Screenings per 100 cubic feet of solid ground wood, bone-dry.	Average temperature of grinding.	Horsepower divided by pressure X speed.
	Kind of burr.	Surface.						Feet per minute.	P. ct.								Lbs.						
Western yellow pine—Western larch. Do.	Spiral, cut 12 to inch.	Same surface—do.	24	3	Lbs. per sq. in.	16.4	200	2,728	389.0	415	3,290	118.7	173	25.03	9	26.25	2,198	84.4	6.14	159.1	0.00869		
			25	3	40	16.4	200	2,728	360.0	401	3,115	115.7	210	25.03	9	26.25	2,170	84.2	6.14	154.8	.00803		
Western larch—western hemlock. Western, hemlock—Sitka spruce.	do.	do.	26	3	40	16.4	200	2,728	373.0	415	3,275	114.0	104	25.03	Split..	26.25	2,268	88.9	9.73	156.7	.00833		
			15	3	40	16.4	200	2,728	323.0	352	2,353	137.2	109	24.62	Split..	23.84	2,212	92.1	8.26	154.0	.00721		
Do.	do.	do.	16	3	40	16.4	200	2,728	312.0	392	2,163	144.0	65	24.62	do.	22.26	2,100	88.5	9.82	153.2	.00896		
			17	3	40	16.4	200	2,728	347.0	392	2,348	148.0	139	24.62	do.	22.26	2,190	90.5	9.23	163.0	.00774		
Montana lodgepole pine—western larch. Do.	do.	do.	24	3	40	16.4	200	2,728	377.0	405	3,235	116.5	176	24.37	73	24.76	2,180	84.7	5.99	151.2	.00841		
			25	3	40	16.4	200	2,728	403.0	458	3,300	122.1	229	24.37	73	24.76	2,138	85.1	2.96	154.8	.00900		
California lodgepole pine—red fir. Do.	do.	do.	22	3	40	16.4	200	2,728	366.0	410	2,095	175.0	113	21.65	Split..	27.65	1,917	87.5	8.82	170.2	.00817		
			23	3	40	16.4	200	2,728	391.0	437	2,650	147.6	92	21.65	do.	27.65	2,016	91.6	7.29	157.3	.00874		
Do.	do.	do.	24	3	40	16.4	200	2,728	376.0	431	2,137	176.0	157	22.14	do.	27.65	1,860	85.2	7.94	170.1	.00840		
			25	3	40	16.4	200	2,728	377.0	444	2,270	166.0	117	21.65	do.	27.65	1,988	88.4	24.90	162.7	.00842		
California lodgepole pine—Sitka spruce. Balsam-spruce.	Spiral, cut 8 to inch, straight, cut 10 to inch.	Stone dressed—do.	23	3	40	16.4	225	3,069	476.0	542	4,980	95.6	254	20.30	5 1/2	33.55	2,160	96.2	11.50	157.0	.00945		
			63	3	50	20.5	225	3,069	516.0	592	4,075	127.0	179	24.93	5 1/2	33.55	2,280	92.1	12.00	177.0	.00820		
Spruce-hemlock.	do.	do.	54	2	65	26.6	225	3,069	415.0	503	4,705	88.2	205	23.74	4	35.13	2,410	89.4	13.75	157.0	.00509		

NOTE.—Wood for runs 50-52, inclusive, was steamed for 5 hours at 75 pounds.

Kind of wood.	Run No.	Dura- tion of treat- ment.	Pressure of treat- ment.	Kind of wood.	Run No.	Dura- tion of treat- ment.	Pressure of treat- ment.	Kind of wood.	Run No.	Dura- tion of treat- ment.	Pressure of treat- ment.	Kind of wood.	Run No.	Dura- tion of treat- ment.	Pres- sure of treat- ment.
		Hours.	Pounds.			Hours.	Pounds.			Hours.	Pounds.			Hours.	Pounds.
Balsam fir.....	7	8	60	Tamarack.....	19	4	60	Tamarack.....	72	6	75	Englemann spruce (Colorado).....	13	6	60
	15	5	75		20	8	20		73	4	75		14	6	60
	16	5	75		21	8	40		74	3	75		15	6	60
	17	5	75		22	8	60		75	2	75		16	6	60
	25	5	75		23	8	60		76	1	75		17	4	60
	26	5	75		24	8	60	Western larch.....	1	8	60		18	6	20
	27	5	75		25	8	60								
	28	5	75		26	8	60	Montana lodge- pole pine.....	8	8	60	Englemann spruce (Montana).....	8	6	60
	29	5	75		27	8	60		13	5	75		10	6	60
Red fir.....	2	8	60		30	8	60		14	5	75				
					31	8	75		15	5	75	Sitka spruce.....	5	5	75
White fir.....	21	6	60		32	5	75						6	5	75
	22	6	60		33	5	75						7	5	75
	23	6	60		34	5	75	California lodge- pole pine.....	1	8	60		16	12	5
	24	6	60		35	5	75						17	5	75
	25	6	40		36	5	75	Western yellow pine	1	6	40				
	26	6	20		37	5	75		2	4	60	Poplar.....	1	8	60
					38	5	75		3	8	75		3	5	75
Amabilis fir.....	9	6	60		39	5	75		8	5	75		4	5	75
	10	6	60		40	5	75		9	5	75		5	5	75
	11	6	60		41	5	75		10	5	75				
	12	6	60		42	5	75		11	5	75	White birch.....	1	8	60
	13	6	60		43	5	75		12	12	5		3	5	75
	14	6	20		44	5	75		11	5	5		4	5	75
					45	5	75						5	5	75
Alpine fir.....	9	6	60		46	5	75	White pine.....	9	6	60				
	10	6	60		47	12	5		10	6	60		9	6	30
	11	6	60		48	5	75		11	6	60		10	6	60
	12	6	60		49	5	75		12	6	60	Black gum.....	11	6	60
					55	5	75						12	6	60
Lowland fir.....	1	6	60		56	5	75	Jack pine.....	25	2	40		9	5	75
	2	6	60		57	5	75		26	8	60	Western hemlock...			
	3	6	60		58	5	75		28	5	75		16	6	60
					59	5	75		29	5	75	Loblolly pine.....	17	6	60
Noble fir.....	9	6	60		60	5	75		30	5	75		18	6	60
	10	6	60		61	5	75		31	5	75		19	6	60
	11	6	60		62	5	75		32	12	5		20	6	30
	12	6	30		63	5	75		33	5	75				
					64	5	75	Eastern hemlock...	53	5	40				
Tamarack.....	12	4	40		65	5	75		54	2	60				
	13	2	20		66	5	75		55	8	60				
	15	2	40		67	5	75		60	5	75				
	16	2	60		68	5	75		61	5	75				
	17	4	20		69	12	75		62	5	75				
	18	4	40		70	10	75								
					71	8	75								

¹ For the wood used in grinder run No. 38, tamarack, the temperature of treatment was only 255° F.

TABLE 33.—*Quality tests—balsam.*

Grinder run No.	Paper machine run No.	Mullen test.				Schopper tests.						Tintometer indications.					
		Total.	Per 0.001 in. thickness.	Per pound.	Horsepower per ton divided by strength factor.	Breaking length.			Stretch.		Breaking weight per sq. mm. sectional area.	Breaking length per horsepower per ton.	Red.	Green.	Blue.	Black.	
						Meters.	Lengthwise.	Average.	Per ct.	Crosswise.							Lengthwise.	Average.	Per ct.
		Points.	Points.	Points.		Meters.	Meters.	Meters.	Per ct.	Per ct.	Grams.	Meters.	Parts.	Parts.	Parts.	Parts.	Parts.
1	104	17.95	4.60	0.498	282	3,685	5,530	4,008	2.16	1.24	1,295	32.8	82	72	64	82	82
2	103	13.25	3.40	0.401	250	3,030	4,910	3,970	1.84	1.16	1,835	39.6	81	67	64	84	84
3	111	10.40	2.54	0.336	246	2,285	3,297	2,791	2.18	1.16	1,225	33.8	87	76	67	83	83
4	115	14.95	4.69	0.482	369	3,140	4,670	3,905	2.86	1.52	2,265	22.0	80	72	65	80	80
5	116	14.70	4.22	0.445	273	2,908	4,470	3,689	3.16	1.52	1,970	30.4	82	72	64	82	82
6	242	14.6	4.4	0.48	258	3,000	5,280	4,140	1.98	1.20	2,010	33.4	51	36	30	183	183
7	224	17.2	4.8	0.51	366	3,280	6,130	4,700	1.96	1.28	2,370	25.1	73	63	57	106	106
8	241	13.6	3.8	0.43	309	3,040	4,970	4,000	1.84	1.22	1,800	30.1	72	63	58	107	107
9	211	12.4	3.5	0.42	257	2,870	5,080	3,980	1.76	1.28	1,780	36.9	75	66	60	99	99
10	240	14.4	4.2	0.46	529	3,260	5,710	4,580	1.92	1.20	2,180	18.4	73	64	57	106	106
11	225	14.8	4.2	0.46	300	2,940	4,930	3,940	1.88	1.26	1,780	24.8	76	67	61	96	96
12	238	12.4	3.4	0.40	276	3,050	5,400	4,260	1.92	1.28	2,000	35.8	70	61	55	114	114
13	239	14.6	4.0	0.47	346	3,860	6,200	5,030	2.12	1.28	3,450	27.5	35	22	16	227	227
14	218	27.0	7.4	0.60	346	3,860	6,200	5,030	2.12	1.28	3,450	24.2	42	26	21	211	211
15	270	31.0	7.7	0.65	267	3,340	6,630	4,980	1.80	1.38	3,120	28.7	38	22	16	221	221
16	277	28.4	7.3	0.62	270	3,160	5,790	4,470	1.72	1.38	3,010	26.6	38	22	16	222	222
17	302	14.8	4.1	0.46	267	2,960	5,040	4,000	2.28	1.34	1,940	32.6	71	58	49	122	122
18	338	15.5	4.1	0.46	267	2,960	5,040	4,000	2.28	1.34	1,940	33.3	81	71	59	89	89
19	339	14.5	3.9	0.45	285	3,090	5,220	4,010	2.34	1.48	1,840	32.5	75	61	50	114	114
20	329	14.5	3.9	0.45	285	3,090	5,220	4,010	2.84	1.62	1,950	32.8	80	66	56	98	98
21	340	13.2	3.4	0.42	410	2,640	3,140	2,410	2.12	1.36	1,880	26.7	70	65	65	100	100
22	16	6.8	2.4	0.22	277	3,090	5,220	4,410	.96	1.18	1,880	40.3	80	69	60	91	91
23	449	13.2	3.1	0.32	292	2,640	4,650	3,640	2.16	1.18	1,580	35.2	79	69	64	88	88
24	741	10.8	2.6	0.32	322	2,080	4,630	3,360	1.12	1.88	1,450	42.6	49	38	34	182	182
25	484	23.1	8.3	0.70	206	3,210	6,920	5,080	2.96	1.32	3,440	35.2	48	36	31	185	185
26	485	17.8	6.6	0.57	187	3,210	6,840	5,020	2.70	1.26	3,330	47.1	50	37	32	181	181
27	486	20.6	7.5	0.64	156	3,360	6,820	5,090	3.22	1.16	3,170	50.9	52	38	32	178	178
28	481	20.2	7.0	0.61	162	3,400	6,040	4,720	2.16	1.22	3,170	47.8	52	38	32	177	177
29	487	21.2	7.2	0.62	165	3,170	6,190	4,680	2.86	1.40	3,120	45.9	52	38	32	177	177

1 Commercial.

TABLE 34.—Quality tests—red fir.

Grinder run No.	Paper machine run No.	Ground wood in total furnish.	Weight per ream.	Thickness.	Mullen test.			Schopper tests.						Tintometer indications.						
					Total.	Per 0.001 in. thick-ness.	Per pound.	Horsepower per ton divided by strength factor.	Breaking length.			Stretch.		Breaking weight per sq. mm. sec.	Breaking length per horsepower	Red.	Green.	Blue.	Black.	
									Crosswise.	Lengthwise.	Average.	Crosswise.	Lengthwise.							Average.
1	65	80	30	0.0040	8.3	Points.	Point.	236	Meters.	3,580	2,868	Per ct.	0.88	Per ct.	1,108	44.0	83	68	60	89
2	235	80	36	.0035	18.7	2.08	.52	242	2,800	5,480	4,140	1.14	0.88	2,220	33.0	44	30	23	203	
4	212	80	29	.0034	10.4	3.1	.56	323	3,110	5,950	4,530	1.74	1.48	2,030	25.0	72	59	52	117	
6	395	82	32	.0037	17.6	4.8	.55	382	3,290	5,930	4,610	1.36	1.10	2,180	22.0	64	52	47	137	
7	398	80	32	.0037	14.5	3.9	.45	749	3,170	5,500	4,370	1.94	1.08	2,060	13.0	64	49	42	145	
8	396	80	36	.0040	18.0	4.5	.30	616	3,080	5,740	4,410	1.48	1.06	2,220	14.3	62	50	45	143	
9	391	80	34	.0041	12.8	3.1	.38	680	2,430	4,790	3,620	1.80	1.28	1,640	14.0	60	48	42	150	
10	390	80	40	.0042	18.8	4.6	.47	664	3,190	5,740	4,400	2.20	1.28	2,240	14.3	66	54	47	133	
11	392	79	41	.0046	16.4	3.6	.40	527	2,880	5,530	4,200	1.44	1.08	2,080	19.9	70	55	48	127	
12	393	80	36	.0040	15.4	3.8	.43	504	2,790	5,180	3,980	1.48	1.02	1,880	18.4	70	56	50	124	
13	400	80	35	.0040	14.6	3.6	.42	436	3,080	5,480	4,280	1.52	1.04	2,000	23.3	65	51	45	139	
14	394	80	31	.0039	11.0	2.8	.35	415	2,600	4,440	3,520	1.16	.90	1,530	24.3	71	58	51	120	
15	326	80	33	.0038	14.6	3.9	.45	326	2,800	4,440	3,590	2.54	1.40	1,760	24.5	61	53	49	137	
16	401	80	28	.0034	12.0	3.5	.43	292	2,710	5,300	4,000	1.40	1.04	1,740	32.0	65	54	50	131	
17	397	80	32	.0040	13.2	3.3	.41	247	3,050	5,020	4,040	1.70	1.04	1,740	39.9	72	59	51	118	
18	399	80	31	.0039	9.9	2.5	.32	265	2,700	4,440	3,570	1.14	.84	1,370	42.1	71	57	57	115	
19	cml. 8	75	34	.0034	9.9	2.9	.29	272	1,850	3,550	2,700	1.52	.96	1,660	31.9	58	54	53	135	
	451	80	33	.0043	10.8	2.5	.33	256	2,650	4,150	3,400	2.00	1.08	1,450	40.1	70	55	51	124	

TABLE 35.—Quality tests—white fir.

Mullen test.				Schopper tests.						Tintometer indications.											
Grinder run No.	Paper machine run No.	Ground wood in total furnish.	Weight per ream.	Thickness.	Total.			Per 0.001 in. thickness.	Per pound.	Horsepower per ton divided by strength factor.	Breaking length.			Stretch.		Breaking weight per sq. mm. sec. additional area.	Breaking length per horsepower per ton.	Red.	Green.	Blue.	Black.
					Points.	Points.	Points.				Meters.	Lengthwise.	Meters.	Per ct.	Crosswise.							Lengthwise.	Average.
1	459	80	36	0.0050	10.0	2.0	0.28	472	2,080	3,440	2,760	1.74	0.90	1.32	1,150	20.9	70	63	58	Parts.	
2	460	80	37	0.0047	8.8	1.9	0.24	448	2,070	3,390	2,730	1.62	0.90	1.33	1,260	25.4	72	65	59	Parts.	
3	461	80	33	0.0043	8.0	1.9	0.24	369	2,020	3,310	2,660	1.46	0.90	1.18	1,230	30.0	73	66	59	Parts.	
4	462	80	32	0.0040	6.9	1.7	0.22	394	1,980	3,190	2,580	1.28	0.88	1.08	1,200	29.7	75	66	59	Parts.	
5	463	80	37	0.0045	9.4	2.1	0.25	363	2,200	3,580	2,890	1.64	0.98	1.31	1,340	31.9	70	63	55	Parts.	
6	464	80	36	0.0045	7.4	1.6	0.21	407	1,900	3,100	2,500	1.10	0.86	0.98	1,140	29.2	70	63	55	Parts.	
7	465	80	34	0.0042	7.4	1.8	0.22	380	1,840	2,980	2,410	1.16	0.86	1.01	1,140	28.8	73	65	57	Parts.	
8	466	80	31	0.0038	9.7	2.6	0.31	374	1,760	2,450	2,260	1.46	1.00	1.23	1,590	28.2	71	63	57	Parts.	
9	519	80	36	0.0043	8.4	2.0	0.24	421	1,640	2,090	2,360	1.68	1.08	1.38	1,110	23.4	74	63	56	Parts.	
10	520	80	38	0.0044	11.7	2.6	0.31	370	2,000	3,790	2,900	1.44	0.82	1.13	1,400	31.2	72	65	58	Parts.	
11	506	80	38	0.0046	8.8	1.9	0.23	370	1,500	2,890	2,200	1.90	1.24	1.57	1,070	25.8	76	64	57	Parts.	
12	507	80	42	0.0042	16.5	3.9	0.39	280	2,880	4,480	3,430	2.34	1.44	1.89	1,990	31.4	81	71	63	Parts.	
13	508	80	42	0.0043	15.2	3.5	0.36	300	2,000	4,290	3,140	2.44	1.56	2.00	1,780	29.0	79	70	62	Parts.	
14	509	80	42	0.0048	12.4	2.6	0.30	290	1,960	3,460	2,710	2.00	1.10	1.55	1,380	31.1	80	72	64	Parts.	
15	510	80	43	0.0048	12.6	2.6	0.29	291	1,850	3,550	2,700	2.04	1.20	1.62	1,380	32.0	79	70	62	Parts.	
16	511	80	46	0.0050	12.2	2.4	0.27	397	1,880	3,440	2,660	1.54	1.18	1.36	1,460	24.8	72	64	57	Parts.	
17	512	80	41	0.0046	11.8	2.5	0.26	345	1,990	3,610	2,800	1.76	1.10	1.43	1,470	28.0	74	64	59	Parts.	
18	513	80	46	0.0054	11.9	2.2	0.26	328	1,730	3,240	2,480	1.46	1.06	1.26	1,220	29.1	76	67	60	Parts.	
19	514	80	30	0.0038	6.2	1.7	0.21	358	1,650	2,860	2,260	1.16	0.82	0.99	1,040	30.0	76	65	59	Parts.	
20	517	100	50	0.0042	25.2	6.0	0.50	240	2,640	5,680	4,160	2.04	1.22	1.62	2,910	34.7	46	33	28	Parts.	
21	527	100	38	0.0033	18.0	5.4	0.47	242	2,380	5,200	3,790	1.56	1.04	1.30	2,490	33.2	49	36	30	Parts.	
22	496	100	35	0.0032	10.7	3.3	0.31	318	1,830	3,250	2,540	1.22	0.80	1.01	1,610	25.8	49	36	30	Parts.	
23	495	100	35	0.0032	10.7	3.3	0.31	318	1,830	3,250	2,540	1.22	0.80	1.01	1,610	25.8	49	36	30	Parts.	
24	526	100	49	0.0042	17.4	4.1	0.36	273	2,160	4,870	3,560	1.92	1.04	1.48	2,330	36.7	50	35	29	Parts.	
25	536	100	52	0.0052	18.1	3.5	0.35	273	2,160	4,870	3,560	1.92	1.04	1.48	2,330	36.7	50	35	29	Parts.	
26	537	100	46	0.0053	10.0	1.9	0.22	405	1,480	3,860	3,010	2.38	1.06	1.72	1,830	31.5	58	43	35	Parts.	
27	591	80	36	0.0040	10.0	1.9	0.22	405	1,480	3,860	3,010	2.38	1.06	1.72	1,830	31.5	58	43	35	Parts.	
28	594	80	37	0.0042	14.2	3.6	0.40	282	2,640	5,300	3,970	1.82	1.12	1.47	2,040	35.1	71	63	59	Parts.	
29	592	80	41	0.0042	14.7	3.5	0.40	283	2,670	5,250	3,960	1.78	1.20	1.46	2,040	36.9	73	63	57	Parts.	
30	587	80	38	0.0041	12.8	3.1	0.34	278	2,480	4,420	3,450	2.36	1.12	1.74	1,810	36.5	77	68	59	Parts.	
31	593	80	34	0.0042	10.2	2.4	0.30	373	2,180	4,030	3,100	1.66	1.04	1.35	1,560	27.7	70	63	54	Parts.	
32	589	80	34	0.0041	10.6	2.8	0.31	368	2,630	3,680	2,880	1.52	1.04	1.35	1,406	27.6	71	61	53	Parts.	
33	588	80	34	0.0044	10.0	2.2	0.29	420	2,880	4,030	3,450	2.36	1.04	1.74	1,810	36.5	77	68	59	Parts.	
34	590	80	34	0.0048	13.8	2.9	0.31	338	2,630	3,680	2,880	1.52	1.04	1.35	1,406	27.6	70	62	53	Parts.	
35	649	80	34	0.0043	7.2	2.2	0.21	383	1,420	2,840	2,160	1.62	1.12	1.37	1,760	29.2	69	57	53	Parts.	
35 cm.	649	80	33	0.0041	8.2	2.0	0.25	322	2,070	5,510	2,730	1.32	0.78	0.89	1,370	26.9	75	60	58	Parts.	

1 Wood from tree 18 inches in diameter.

2 Wood from tree 42 inches in diameter.

TABLE 36.—Quality tests—Alpine fir.

Grinder run No.	Paper machine run No.	Ground wood in total furnish.	Weight per ream.	Thickness.	Mullen test.				Schopper tests.						Tintometer indications.					
					Total.	Per 0.001 in. thick- ness.	Per pound.	Horsepower per ton divided by strength factor.	Breaking length.			Stretch.		Breaking weight per sq. mm. sec- tional area.	Breaking length per horsepower	Red.	Green.	Blue.	Black.	
									Crosswise.	Lengthwise.	Average.	Crosswise.	Lengthwise.							Average.
1	580	80	22	0.0026	7.1	2.7	0.32	368	2,070	3,790	2,930	2.70	1.12	1.95	1,430	24.9	81	73	65	81
2	581	80	36	0.0040	11.6	2.9	.32	290	2,090	3,700	2,900	2.94	1.48	2.21	1,500	31.2	83	75	66	76
3	579	80	30	0.0035	9.0	2.5	.30	262	1,980	1,780	1,880	2.30	1.32	1.81	1,490	23.9	83	74	67	76
4	578	80	35	0.0042	9.0	2.1	.26	292	1,850	2,960	2,400	2.42	1.22	1.82	1,180	31.6	82	74	68	76
5	582	80	32	0.0035	12.0	3.4	.38	262	2,240	4,180	3,210	1.32	1.38	2.25	1,660	32.2	83	75	67	75
6	577	78	35	0.0038	13.0	3.4	.37	264	2,090	4,150	3,120	1.34	1.46	2.40	1,600	32.0	83	75	68	74
7	576	80	37	0.0044	12.8	2.9	.35	265	2,650	4,600	3,620	1.94	1.02	1.48	1,550	39.1	81	74	67	78
8	575	80	34	0.0041	11.6	2.8	.34	252	2,840	4,850	3,840	1.80	1.06	1.43	1,960	44.8	82	75	68	75
9	557	100	43	0.0039	28.2	7.3	.66	188	3,200	6,970	5,080	3.04	1.40	2.20	3,230	41.0	54	42	36	168
10	558	100	37	0.0035	22.5	6.5	.61	155	1,990	5,660	3,820	1.60	1.20	1.40	2,320	40.3	55	42	35	168
11	559	100	45	0.0044	25.4	5.8	.56	159	2,080	5,200	3,640	1.68	1.04	1.36	2,210	40.9	56	41	35	168
12	560	100	41	0.0038	25.2	5.7	.62	142	2,180	6,300	4,240	1.40	1.26	1.33	2,630	48.0	53	39	32	176
13	114	80	33	0.0029	9.2	3.1	.28	300	1,670	3,020	2,340	1.16	1.68	.92	1,680	27.8	68	61	63	108
13	640	80	35	0.0043	12.3	2.9	.35	240	2,830	5,120	3,980	1.70	1.06	1.38	1,720	47.4	76	70	67	87

1 Commercial.

TABLE 37.—Quality tests—*Amabilis fir*.

Grinder run No.	Paper machine run No.	Ground furnish.	Weight per ream.	Thickness.	Mullen test.				Schopper tests.						Tintometer indications.				
					Total.	Per 0.001 in. thick- ness.	Per pound.	Horsepower per ton divided by strength factor.	Breaking length.			Stretch.		Breaking weight per sq. mm. sec- tional area.	Breaking length per horsepower	Red.	Green.	Blue.	Black.
									Crosswise.	Lengthwise.	Average.	Crosswise.	Lengthwise.							Average.
1	595	80	36	0.0040	16.3	4.1	0.45	205	2,560	4,900	3,730	1.92	1.06	1.49	2,170	71	62	58	109
2	596	80	41	0.0045	16.8	3.7	.41	197	2,750	4,830	3,790	2.24	1.04	1.64	2,060	71	63	58	108
3	621	80	37	0.0042	14.0	3.4	.38	186	2,520	4,520	3,520	2.26	1.18	1.72	1,790	76	66	60	98
4	620	80	36	0.0042	12.5	3.0	.35	189	2,510	4,240	3,380	1.82	1.14	1.48	1,680	74	64	59	103
5	583	80	31	0.0034	10.8	3.2	.34	265	1,980	3,950	2,960	2.74	1.42	2.08	1,630	72	64	59	105
6	585	80	37	0.0039	16.8	4.4	.45	208	3,010	5,480	4,240	3.12	1.28	2.20	2,310	77	67	61	95
7	586	80	35	0.0038	14.6	3.8	.42	217	2,540	4,840	3,690	2.25	1.24	1.75	2,030	75	65	59	101
8	584	79	31	0.0034	11.7	3.4	.38	206	2,490	4,420	3,460	1.96	1.08	1.52	1,770	77	69	62	92
9	582	100	43	0.0038	25.0	6.6	.56	230	3,830	6,160	5,000	2.34	1.92	1.63	3,390	32	29	32	195
10	551	100	40	0.0030	28.5	8.1	.65	152	2,900	6,120	4,510	2.62	1.14	1.88	3,180	44	37	32	180
11	552	100	37	0.0030	24.1	8.1	.65	160	3,720	5,700	4,710	3.34	1.98	2.16	3,360	47	36	31	186
12	549	100	36	0.0030	20.6	6.8	.57	172	3,260	5,240	4,250	3.74	1.00	2.07	2,860	51	38	32	179
13	553	100	34	0.0029	19.0	6.6	.56	198	2,820	5,620	4,220	1.74	1.98	1.36	2,920	54	42	36	168
14	550	100	40	0.0038	24.2	6.4	.60	166	3,110	5,740	4,420	3.08	1.44	2.26	2,720	65	55	47	133
15	117	80	36	0.0033	10.2	3.1	.28	290	1,870	3,700	2,780	1.28	1.74	1.01	1,860	68	61	60	111
15	653	80	33	0.0038	13.8	3.7	.42	193	2,770	5,130	3,950	2.74	1.38	2.06	2,070	72	63	59	106

1 Commercial.

TABLE 38.—*Quality tests—lowland fir.*

Grinder run No.	Paper machine run No.	Ground wood in total furnish.	Weight per ream.	Thickness.	Mullen test.			Schopper tests.						Tintometer indications.							
					Total.	Per 0.001 in. thickness.	Per pound.	Horsepower per ton divided by strength factor.	Breaking length.			Stretch.		Breaking weight per sq. mm. sec.	Breaking length per horsepower	Red.	Green.	Blue.	Black.		
									Points.	Points.	Points.	Meters.	Crosswise.							Lengthwise.	Average.
		Per ct.	Pounds.	Inch.	Points.	Points.	Points.		Meters.	Crosswise.	Lengthwise.	Average.	Per ct.	Grams.	Meters.	Parts.	Parts.	Parts.	Parts.		
1	692	100	46	0.0042	25.3	6.0	0.55	154	3,850	6,700	5,280	1.74	1.03	3,510	62.4	50	37	32	181		
2	691	100	45	0.0043	25.0	5.9	0.55	145	3,800	7,340	5,570	2.10	1.14	3,540	69.6	50	37	31	182		
3	681	100	39	0.0036	22.0	6.1	0.56	147	3,300	5,790	4,540	1.84	1.02	2,920	55.3	46	34	30	190		
4	717	80	38	0.0045	13.5	3.0	0.35	199	2,880	5,530	4,200	1.58	0.96	1,900	60.4	76	66	62	96		
5	716	80	36	0.0046	10.4	2.3	0.29	216	2,340	4,580	3,460	1.48	0.80	1,470	55.3	78	67	61	94		
6	713	80	35	0.0044	9.2	2.1	0.26	236	1,960	4,080	3,020	1.28	0.88	1,360	49.2	82	72	65	81		
7	723	80	38	0.0045	14.0	2.1	0.37	220	2,550	5,160	3,860	1.90	1.12	1,790	47.4	78	70	63	89		
8	712	80	30	0.0044	10.6	2.4	0.29	281	2,360	4,440	3,400	1.66	0.92	1,920	41.7	78	68	63	91		
9	729	80	30	0.0037	12.0	3.2	0.40	202	2,770	6,020	4,400	1.44	0.96	1,960	54.5	76	67	61	96		
10	724	80	38	0.0046	13.0	2.8	0.34	243	2,750	5,120	3,940	1.50	0.92	1,760	47.6	78	70	62	90		
11	715	80	37	0.0044	13.1	3.0	0.35	208	2,780	5,120	3,950	1.80	0.88	1,800	52.8	80	67	61	92		
12	725	80	41	0.0048	15.0	3.1	0.36	260	2,480	5,180	3,830	1.64	1.02	1,333	42.2	80	70	65	85		
13	730	80	37	0.0042	17.0	4.0	0.46	170	2,950	6,130	4,540	2.04	1.14	2,140	58.0	76	68	61	95		
14	708	80	39	0.0044	13.0	2.9	0.33	213	2,610	4,900	3,760	1.52	0.92	1,222	53.5	82	73	67	78		
15	720	80	37	0.0042	13.2	3.1	0.36	231	2,630	5,140	3,880	1.78	1.04	1,411	46.7	73	65	60	102		
16	722	80	35	0.0042	14.2	3.4	0.41	205	2,640	5,450	4,040	1.78	1.00	1,860	48.0	77	67	62	94		
17	709	80	34	0.0039	12.4	3.1	0.36	230	2,800	5,200	4,000	1.76	0.94	1,800	48.4	83	73	68	76		
17	726	80	33	0.0041	12.6	3.1	0.38	211	2,760	5,640	4,200	1.58	0.92	1,780	52.3	81	70	62	87		

TABLE 39.—*Quality tests—noble fir.*

Grinder run No.	Paper machine run No.	Mullen test.				Schopper tests.						Tintometer indications.					
		Total.	Per 0.001 in. thickness.	Per pound.	Horsepower per ton divided by strength factor.	Breaking length.			Stretch.		Breaking weight per sq. mm. sec.	Breaking length per horsepower	Red.	Green.	Blue.	Black.	
						Crosswise.	Lengthwise.	Average.	Crosswise.	Lengthwise.							Average.
		Points.	Points.	Point.		Meters.	Meters.	Meters.	Per ct.	Per ct.	Per ct.	Grams.	Meters.	Parts.	Parts.	Parts.	Parts.
1	735	18.8	5.3	0.59	190	2,690	6,490	4,590	3.04	1.54	2.29	2,220	41.0	72	62	58	108
2	641	15.5	4.5	.46	185	3,140	5,960	4,550	1.92	1.12	1.52	2,340	53.5	73	67	60	100
3	658	15.3	4.1	.44	181	2,890	5,560	4,220	2.42	1.40	1.91	2,220	53.0	73	64	60	103
4	639	15.6	3.9	.42	165	3,090	5,440	4,260	2.20	1.14	1.67	2,090	61.3	73	63	53	111
5	642	19.0	5.2	.51	164	3,250	6,580	4,920	2.38	1.16	1.77	2,520	59.0	72	62	59	107
6	646	17.8	5.2	.54	148	3,500	6,510	5,000	1.98	1.02	1.50	2,710	62.7	71	62	57	110
7	736	18.4	4.9	.56	155	3,120	6,530	4,820	3.10	1.46	2.28	2,380	55.5	72	63	57	108
8	643	16.9	4.4	.47	179	3,040	5,950	4,500	2.22	1.16	1.69	2,420	53.4	72	62	57	109
9	706	22.5	6.9	.56	171	3,810	6,730	5,270	1.60	.90	1.25	3,610	55.2	50	35	30	185
10	701	23.0	6.9	.55	166	4,020	6,020	5,020	2.18	1.04	1.61	3,700	55.0	50	37	31	182
11	700	28.4	8.7	.69	138	4,320	7,270	5,800	2.64	1.10	1.87	4,200	60.7	50	37	31	182
12	663	16.0	4.9	.50	202	3,120	6,600	4,800	1.62	1.02	1.32	2,820	48.1	59	49	41	151
13	654	15.1	4.0	.43	179	3,100	5,870	4,480	2.70	1.40	2.05	2,180	58.2	72	64	58	106
14	734	24.9	6.0	.61	133	3,160	7,050	5,100	3.82	1.70	2.76	2,740	62.7	71	63	57	109
15	645	13.4	3.8	.42	222	2,820	5,320	4,070	2.03	1.10	1.59	2,170	43.7	72	64	60	104
16	113	12.6	4.5	.36	256	2,260	4,630	3,440	1.60	.96	1.28	2,710	37.4	63	56	55	106
17	647	16.6	4.8	.49	188	3,370	6,240	4,800	1.95	1.04	1.50	2,610	52.2	72	65	60	103
18	731	14.8	3.5	.42	144	2,930	5,920	4,420	1.70	1.08	1.39	1,960	72.8	71	62	56	111
19	737	17.9	4.7	.54	133	3,010	5,970	4,490	2.60	1.20	1.90	2,160	62.4	72	62	58	108

1 Commercial.

Grinder run No.	Paper machine run No.	Ground wood in total furnish.	Weight per ream.	Thickness.	Mullen test.				Schopper tests.						Tintometer indications.			
					Total.	Per 0.001 in. thickness.	Per pound.	Horsepower per ton divided by strength factor.	Breaking length.		Stretch.		Breaking weight per sq. mm. sectional area.	Breaking length per horsepower per ton.	Red.	Green.	Blue.	Black.
									Crosswise.	Lengthwise.	Average.	Crosswise.							Lengthwise.	Average.
		Per ct.	Pounds.	Inch.	Points.	Points.	Point.	Meters.	Meters.	Per ct.	Per ct.	Grams.	Meters.	Parts.	Parts.	Parts.	Parts.	
53	107	80	32	0.00436	10.8	2.48	0.338	2,385	3,725	0.72	1.19	1,295	40.3	71	59	51	119	
54	105	80	33	0.0046	10.25	2.23	.311	2,135	3,425	.92	1.07	1,150	37.6	75	61	54	110	
55	232	80	35	0.0035	15.2	4.30	.44	2,540	4,660	2.62	1.82	1,890	29.0	45	29	23	203	
56	219	80	30	0.0038	9.2	2.4	.31	2,470	4,530	1.34	1.18	1,490	16.7	66	57	52	125	
60	257	100	54	0.0048	28.2	5.9	.52	3,070	5,870	2.48	1.50	2,820	22.6	42	27	20	211	
61	255	100	54	0.0049	28.3	5.8	.52	3,000	5,810	2.62	1.60	2,600	33.2	41	26	20	214	
62	256	100	55	0.0047	28.3	6.0	.51	2,860	5,620	3.22	1.58	2,730	32.5	41	26	19	213	

NOTE.—For run No. 63 see Mixture of woods.

TABLE 41.—Quality tests—western hemlock.

Grinder run No.	Paper machine run No.	Ground wood in total furnish.	Weight per ream.	Thickness.	Mullen test.				Schopper tests.						Tintometer indications.				
					Total.	Per 0.001 in. thickness.	Per pound.	Horsepower per ton divided by strength factor.	Breaking length.			Stretch.		Breaking weight per sq. mm. sectional area.	Breaking length per horsepower per ton.	Red.	Green.	Blue.	Black.
									Crosswise.	Lengthwise.	Average.	Crosswise.	Lengthwise.							Average.
		Per ct.	Pounds.	Inch.	Points.	Points.	Points.		Meters.	Meters.	Per ct.	Per ct.	Grams.	Meters.	Parts.	Parts.	Parts.	Parts.	
1	215	80	31	0.0037	13.4	3.6	0.42	320	2,900	5,700	1.24	1.67	2,000	32.0	62	53	49	136	
5	372	80	37	0.0040	13.6	4.9	.53	245	3,290	4,780	1.48	2.03	2,220	36.8	67	55	48	130	
6	373	80	36	0.0041	16.5	4.0	.46	308	2,760	5,000	1.60	2.02	1,730	27.3	65	55	48	131	
7	403	80	31	0.0033	16.6	5.0	.54	306	3,100	5,740	1.14	1.59	2,170	26.8	66	53	48	133	
8	402	80	26	0.0030	11.3	3.8	.44	436	3,170	5,230	1.70	1.70	1,830	21.8	61	51	45	143	
9	321	100	45	0.0036	28.0	7.8	.62	296	3,440	5,580	1.36	2.02	3,160	24.6	36	22	16	226	
10	352	80	33	0.0035	17.0	4.9	.52	505	3,570	6,350	1.24	1.61	2,340	18.9	63	50	43	141	
11	341	80	32	0.0044	15.9	3.6	.50	171	2,920	4,780	1.32	1.71	1,760	45.1	75	61	53	111	
12	342	80	32	0.0040	10.0	2.7	.34	217	2,650	4,510	1.12	1.36	1,500	48.5	70	57	50	123	
13	353	79	34	0.0043	10.1	2.4	.30	234	2,400	4,320	1.24	1.40	1,360	47.7	71	58	50	121	
14	354	80	33	0.0045	10.4	2.3	.31	201	2,450	4,100	1.12	1.33	1,290	52.5	73	60	51	116	
18	445	75	34	0.0038	10.1	3.6	.31	406	2,430	4,290	1.36	1.92	2,160	26.7	56	53	53	138	
18	445	80	34	0.0039	17.8	4.6	.52	242	3,000	5,720	1.46	2.13	2,080	34.6	64	52	45	139	

NOTE.—For runs 15-17, inclusive, see Mixture of woods.

1 Commercial.

TABLE 42.—*Quality tests—tamarack.*

Grinder run No.	Paper machine run No.	Ground wood in total furnish.	Weight per ream.	Thickness.	Mullen test.			Horsepower per strength factor.	Breaking length.			Stretch.			Breaking weight per sq. mm. sectional area.	Breaking length per horsepower	Tintometer indications.				
					Total.	Per 0.001 in. thickness.	Per pound.		Average.	Crosswise.	Lengthwise.	Average.	Crosswise.	Lengthwise.			Average.	Red.	Green.	Blue.	Black.
Points.	Points.	Points.	Meters.	Meters.	Per ct.	Per ct.	Per ct.	Grams.	Meters.	Parts.	Parts.	Parts.	Parts.								
1	109	80	32	0.00404	12.25	3.04	0.383	235	2,700	4,200	2.48	1.28	1.88	1,570	38.3	83	60	94			
2	55	80	32	.0042	13.40	3.19	.419	430	2,700	4,400	2.48	1.26	1.87	1,600	39.4	69	57	126			
3	15	80	32	.0038	8.00	2.10	.230	287	1,829	3,313	1.21	1.76	1.57	1,199	34.4	73	65	103			
4	31	80	33	.0040	8.90	2.02	.270	287	2,140	3,705	1.23	.78	1.01	1,130	37.8	79	65	104			
5	32	80	32	.0044	11.40	2.85	.356	338	2,400	4,635	1.88	.90	1.39	1,510	25.7	68	50	126			
6	81	80	32	.0043	9.25	2.15	.289	288	1,920	3,760	1.18	.72	.95	1,120	34.1	73	61	115			
7	34	80	32	.0048	8.05	3.82	.252	278	2,376	3,110	2.90	.68	.79	903	33.7	74	61	55			
8	117	80	32	.0035	11.80	1.80	.358	762	2,672	4,365	2.03	1.54	2.24	1,505	11.1	70	39	55			
9	119	60	35	.00372	13.95	3.75	.398	791	2,672	4,365	2.03	1.52	1.80	1,823	11.2	65	60	56			
10	119	60	35	.00372	13.95	3.75	.398	791	2,672	4,365	2.03	1.52	1.80	1,823	11.2	65	60	56			
11	9	80	33	.0051	5.3	1.04	.161	334	1,269	2,625	.83	.74	.78	736	36.2	77	58	49			
12	114	80	33	.00426	9.4	2.203	.2845	240	1,882	2,780	1.98	.92	1.45	1,062	34.0	80	70	62			
13	113	80	34	.00447	8.35	1.866	.2455	277	1,660	2,856	1.90	1.04	1.47	993	33.2	87	77	70			
14	112	80	30	.00344	5.70	1.660	.190	332	1,464	2,065	1.00	.56	.78	986	28.0	65	56	52			
15	88	80	35	.00474	10.35	2.18	.296	250	2,370	3,600	1.20	.80	1.00	1,186	40.4	77	61	54			
16	101	80	33	.00428	11.75	2.74	.356	251	2,565	4,000	1.68	.98	1.31	1,373	36.7	75	59	52			
17	83	80	35	.0044	15.45	3.51	.441	236	2,950	4,740	3,283	1.64	1.51	1,656	36.8	67	51	44			
18	98	80	33	.00387	15.50	4.00	.470	208	3,110	4,800	1.98	1.04	1.51	1,820	40.5	72	58	51			
19	94	80	31	.00498	7.95	1.595	.257	245	2,250	3,310	1.94	.76	.90	1,012	44.3	81	63	55			
20	99	79	33	.00407	13.30	3.26	.403	202	2,924	4,450	3,687	1.96	1.52	1,683	45.2	73	61	58			
21	89	80	33	.00364	15.75	4.33	.477	204	3,000	4,740	3,687	1.96	1.29	1,780	39.8	67	52	43			
22	90	100	30	.0037	9.95	2.79	.332	293	2,515	3,550	1.18	.62	.90	1,315	31.2	52	33	25			
23	84	80	34	.00376	16.25	4.32	.478	175	2,990	4,975	3,983	2.04	1.00	1,975	47.6	51	36	29			
24	100	80	36	.0050	8.5	1.70	.236	292	1,922	3,150	.92	.80	.86	1,037	36.8	83	72	64			
25	25	80	35	.0036	16.8	4.6	.48	210	2,510	5,200	3,860	2.04	1.38	1,950	38.4	43	27	20			
26	226	80	32	.0040	11.2	2.8	.35	455	2,520	4,700	3,610	1.76	1.26	1,51	22.6	64	46	46			
27	282	100	44	.0045	17.5	3.90	.40	151	2,780	4,430	3,600	1.94	1.34	1,64	59.7	44	29	20			
28	288	100	51	.0053	19.0	3.60	.37	173	2,450	3,900	3,180	2.52	1.38	1.95	1,780	49.7	43	27			
29	289	100	45	.0045	17.3	3.80	.38	169	2,410	4,310	3,360	2.05	1.48	1.77	1,910	52.2	43	26	18		
30	281	100	43	.0044	16.6	3.60	.38	194	2,640	4,680	3,660	1.80	1.38	1.59	2,000	49.5	44	28	19		
31	286	100	46	.0050	17.6	3.60	.38	191	2,470	4,040	3,250	1.74	1.26	1.50	1,730	44.9	49	32	24		
32	327	100	46	.0041	18.8	4.60	.41	220	2,870	4,910	3,780	2.32	1.36	1.84	2,270	43.2	40	24	16		
33	273	100	53	.0049	22.4	4.50	.42	200	2,630	4,930	3,890	1.86	1.56	1.71	2,280	44.9	39	23	16		
34	284	100	39	.0038	16.0	4.2	.41	214	2,960	4,950	3,960	1.66	1.32	1.49	2,264	45.0	42	26	21		

35	386	100	38	.0038	16.7	4.4	.44	245	2,770	5,120	3,940	1.60	.94	1.27	2,220	36.6	47	38	24	191
36	383	100	36	.0051	22.6	5.1	.42	245	2,840	5,240	3,880	1.72	1.02	1.37	2,140	47.4	40	33	24	194
37	380	100	43	.0044	22.6	5.1	.51	188	2,750	5,290	3,920	3.18	1.28	2.23	2,270	42.0	42	27	19	212
38	384	80	42	.0049	17.3	3.5	.41	245	2,730	5,040	3,880	2.22	1.46	1.84	1,720	31.8	60	49	40	151
39	389	249	51	.0048	23.2	4.8	.46	278	2,880	5,680	3,780	2.28	.88	1.58	1,670	21.8	35	21	15	229
40	391	100	47	.0044	21.5	5.8	.46	201	2,680	5,030	3,800	2.32	1.36	1.84	2,240	41.7	36	23	17	224
41	254	100	53	.0040	25.8	5.2	.49	196	2,790	5,300	3,940	2.90	1.32	2.21	2,440	42.0	36	23	17	224
42	250	100	47	.0042	21.8	5.0	.46	280	2,850	4,490	3,670	1.90	1.12	1.51	2,220	27.5	36	22	16	225
43	252	100	42	.0038	19.3	5.2	.46	237	2,490	4,800	3,640	1.30	1.34	1.42	2,200	33.4	39	24	17	220
44	253	100	44	.0040	20.2	5.0	.46	224	2,610	4,850	3,730	2.02	1.32	1.67	2,190	36.2	42	26	19	213
45	272	100	55	.0049	24.0	4.9	.44	236	2,610	4,990	3,790	2.22	1.40	1.81	2,270	36.6	42	26	19	213
46	379	100	55	.0049	16.7	3.4	.30	318	2,310	4,280	3,300	1.80	1.28	1.54	2,130	34.6	39	22	14	229
47	327	80	43	.0046	17.5	3.8	.40	725	2,800	4,300	3,550	2.78	1.38	2.08	1,820	12.2	52	41	33	174
48	320	100	52	.0049	21.0	4.3	.40	198	2,680	4,040	3,360	2.34	1.34	1.84	1,990	42.3	41	25	18	216
49	348	80	35	.0047	7.8	1.7	.22	286	1,880	3,190	2,540	1.14	1.07	1.07	970	39.0	66	56	46	192
50	351	75	35	.0033	7.4	2.2	.21	454	1,640	2,960	2,300	1.10	.72	.91	1,400	24.1	52	46	46	156
51	353	80	37	.0045	12.0	2.6	.32	298	2,260	3,950	3,100	1.54	.98	1.26	1,490	32.5	76	63	56	105
52	354	80	53	.0048	23.0	4.8	.43	255	3,210	5,480	4,340	2.20	1.24	1.72	2,910	39.6	42	31	27	270
53	686	100	55	.0048	23.0	4.8	.43	255	3,210	5,480	4,340	2.20	1.24	1.72	2,910	39.6	42	31	27	270
54	689	100	55	.0048	23.0	4.8	.43	255	3,210	5,480	4,340	2.20	1.24	1.72	2,910	39.6	42	31	27	270
55	689	100	49	.0043	23.1	5.3	.47	226	3,230	5,860	4,540	2.16	1.16	1.66	3,030	42.7	44	32	27	197
56	687	100	60	.0052	25.4	4.9	.42	268	2,750	5,100	3,960	1.94	1.24	1.59	2,840	35.2	44	32	27	197
57	683	100	48	.0044	18.8	4.3	.39	308	2,820	5,170	4,000	2.00	1.38	1.69	2,560	33.3	49	25	30	186
58	684	100	50	.0046	20.7	4.5	.41	279	2,820	5,450	4,140	1.50	1.24	1.37	2,670	36.2	43	32	28	193
59	685	100	48	.0042	23.6	5.6	.49	269	3,520	5,000	4,290	1.68	.94	1.31	2,960	32.5	46	33	28	193
60	488	100	44	.0037	14.8	4.0	.34	207	2,130	3,720	2,920	2.20	1.08	1.64	2,160	38.4	43	33	28	194
61	489	100	39	.0036	14.8	4.1	.38	230	1,980	3,300	2,640	2.98	1.36	2.17	1,860	37.1	45	33	28	196
62	490	100	36	.0032	12.7	3.9	.35	230	1,980	3,300	2,640	2.95	1.15	2.05	1,750	32.8	45	33	28	194
63	491	100	36	.0032	14.2	4.5	.40	221	2,400	3,980	3,190	1.52	.84	1.18	2,100	36.1	46	34	28	192
64	492	100	29	.0025	9.5	3.8	.33	286	2,210	3,290	2,750	.96	.63	.80	1,780	29.1	45	34	28	193
65	493	100	37	.0033	15.0	4.6	.40	257	2,420	4,560	3,490	1.73	1.10	1.42	2,260	34.0	42	30	25	203
66	494	100	38	.0032	17.4	5.4	.45	220	2,400	4,560	3,490	1.73	1.10	1.42	2,260	34.0	42	30	25	203
67	493	100	38	.0032	17.4	5.4	.45	220	2,400	4,560	3,490	1.73	1.10	1.42	2,260	34.0	42	30	25	203
68	528	100	44	.0043	12.8	3.1	.29	220	2,400	3,700	2,780	2.16	1.14	1.46	2,480	34.4	44	32	26	198
69	529	100	44	.0043	12.8	3.1	.29	220	2,400	3,700	2,780	2.16	1.14	1.46	2,480	34.4	44	32	26	198
70	531	100	43	.0038	12.2	3.2	.28	252	1,500	3,100	2,300	2.46	1.02	1.74	1,330	32.5	39	27	23	211
71	530	100	43	.0038	12.2	3.2	.28	252	1,500	3,100	2,300	2.46	1.02	1.74	1,330	32.5	39	27	23	211
72	531	100	51	.0046	19.2	4.2	.38	202	1,960	4,180	3,070	3.48	1.46	2.22	1,730	36.8	40	27	23	210
73	532	100	52	.0047	21.1	4.5	.41	185	2,160	4,550	3,360	4.32	1.06	2.09	2,110	45.5	42	30	25	203
74	533	100	50	.0049	16.6	3.4	.33	225	1,890	3,570	2,730	3.32	1.44	2.38	1,650	36.8	49	37	29	189
75	534	100	53	.0055	17.6	3.2	.33	212	1,970	3,480	2,720	3.20	1.40	2.30	1,500	38.4	49	37	29	185
76	535	100	53	.0055	17.6	3.2	.33	212	1,970	3,480	2,720	3.20	1.40	2.30	1,500	38.4	49	37	29	185
77	523	80	40	.0078	12.6	1.6	.20	289	1,660	1,730	1,700	1.76	1.88	1.82	840	29.4	67	56	50	126
78	721	80	39	.0044	16.6	3.8	.42	389	2,720	5,950	4,340	1.94	.98	1.46	2,030	28.5	66	56	50	128
79	721	80	39	.0045	11.2	2.5	.29	639	2,620	4,320	3,470	1.98	1.20	1.59	1,560	18.2	62	52	46	140
80	719	80	40	.0040	18.2	4.6	.45	822	3,000	6,040	4,560	2.14	1.14	1.64	2,470	12.3	62	51	45	142
81	718	80	41	.0043	17.0	4.0	.42	888	2,900	5,900	4,200	1.78	.98	1.38	2,150	11.3	61	50	43	141

1 Commercial.

NOTE.—For runs 50 to 52, inclusive, and run 54 see quality tests—mixtures of woods.

TABLE 43.—*Quality tests—western larch.*

Grinder run No.	Paper machine run No.	Ground wood in total furnish.	Weight per ream.	Thickness.	Mullen test.				Schopper tests.						Tintometer indications.					
					Total.	Per 0.001 in. thickness.	Per pound.	Horsepower per ton divided by strength factor.	Breaking length.			Stretch.		Breaking weight per sq. mm. sec.	Breaking length per horsepower per ton.	Red.	Green.	Blue.	Black.	
									Crosswise.	Lengthwise.	Average.	Crosswise.	Lengthwise.							Average.
1	108	80	33	0.00375	14.9	3.97	0.451	260	2,380	4,620	3,500	2.26	1.28	1.77	1,750	29.8	53	38	29	180
2	221	80	34	.0048	6.6	1.4	.20	518	1,590	2,910	2,250	1.14	.98	1.06	869	21.7	56	42	36	166
3	328	80	39	.0047	10.0	2.2	.26	716	1,980	3,360	2,680	1.94	1.30	1.62	1,250	14.4	81	47	36	136
5	344	80	36	.0042	11.3	2.7	.31	900	2,380	4,310	3,350	1.56	1.26	1.41	1,520	12.0	59	45	35	161
6	739	80	33	.0046	4.4	.9	.13	665	1,160	2,030	1,600	.78	.58	.68	570	18.5	62	48	42	148
7	456	80	39	.0055	9.5	1.7	.24	500	1,770	3,050	2,410	1.40	.90	1.15	1,030	20.0	66	53	46	135
8	457	80	42	.0056	9.6	1.7	.23	420	1,750	2,720	2,240	1.62	1.02	1.32	1,000	23.2	63	52	45	140
9	458	80	40	.0056	7.0	1.3	.18	480	1,500	2,470	1,970	1.42	.92	1.17	830	22.8	61	53	47	136

TABLE 44.—Quality tests—*Montana lodgepole pine*.

GROUND-WOOD PULP.

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Grinder run No.	Paper machine run No.	Ground wood in total furnish.	Weight per ream.	Mullen test.				Schopper tests.				Tintometer indications.							
				Thickness.	Total.	Per 0.001 in. thickness.	Per pound.	Horsepower per ton divided by strength factor.	Breaking length.			Stretch.		Breaking weight per sq. mm. sec.	Breaking length per horsepower	Red.	Green.	Blue.	Black.
									Crosswise.	Lengthwise.	Average.	Crosswise.	Lengthwise.							Average.
1	70	80	32	0.0038	16.15	4.25	0.505	247	3,430	5,780	2.00	1.12	1.58	2,140	37.0	84	70	61	85
2	38	80	33	.0045	14.20	3.16	.430	245	2,325	4,830	2.08	1.18	1.63	1,445	33.9	86	72	62	80
3	30	80	32	.0044	8.90	2.02	.278	250	2,025	4,100	1.16	.84	1.60	1,210	44.1	86	71	62	81
4	2	80	31	.0039	7.30	1.87	.235	272	2,018	4,452	1.34	.86	1.10	1,159	46.6	88	76	68	88
5	36	80	34	.0039	13.25	3.40	.390	277	2,465	5,110	2.14	1.22	1.68	1,810	35.1	81	70	62	87
6	46	80	33	.0039	11.90	3.05	.361	268	2,360	4,440	2.46	1.24	1.85	1,490	35.1	88	71	62	79
7	37	80	30	.0037	8.90	2.40	.296	298	1,923	4,035	2.02	1.10	1.56	1,258	33.7	85	73	66	76
8	7	80	34	.0033	17.35	5.26	.510	203	2,170	5,158	1.55	.98	1.27	1,705	35.4	55	35	27	183
9	222	80	30	.0040	11.6	2.9	.38	299	2,630	4,980	2.16	1.35	1.76	1,600	33.4	80	69	61	90
13	283	100	42	.0034	23.3	7.0	.55	257	3,520	6,950	1.80	1.36	1.58	3,730	37.1	39	22	15	224
14	378	100	46	.0038	30.5	8.0	.66	194	2,820	5,720	4.62	1.52	3.07	3,930	33.4	46	26	18	210
15	280	100	47	.0038	25.2	6.6	.54	246	3,140	6,740	4.40	1.30	1.63	3,040	33.6	40	26	17	217
16	330	80	35	.0045	13.6	3.0	.39	247	2,600	4,300	1.96	1.18	1.65	1,480	35.9	81	70	60	89
17	331	80	36	.0047	14.2	3.0	.39	262	2,600	4,300	2.02	1.18	1.60	1,580	37.1	82	71	60	87
18	346	80	49	.0045	17.1	3.8	.35	316	3,120	5,470	2.12	1.22	1.67	1,880	38.9	81	68	57	94
19	345	80	36	.0044	14.4	3.3	.40	265	2,770	4,720	2.10	1.28	1.69	1,600	35.3	82	67	56	95
20	429	80	30	.0036	12.2	3.4	.40	323	2,880	5,120	1.72	.94	1.33	1,790	31.0	73	64	55	108
21	430	80	30	.0035	13.2	3.8	.44	308	2,930	5,840	1.84	1.00	1.42	2,010	32.3	77	68	59	96
22	431	80	37	.0042	17.4	4.1	.44	231	2,980	5,420	2.10	1.02	1.56	1,980	41.3	79	70	60	91
23	432	80	31	.0040	12.0	3.0	.39	243	2,640	4,530	1.88	.90	1.39	1,550	37.8	80	67	57	96
26	1	75	33	.0028	8.9	3.2	.27	510	1,870	3,980	1.20	.76	.98	1,980	21.2	60	54	54	132
26	447	80	33	.0038	13.8	3.6	.42	328	2,840	4,940	2.34	1.48	1.91	1,850	28.2	71	57	46	126

1 Commercial.

NOTE.—For runs 24 and 25, see Mixture of woods.

TABLE 45.—*Quality tests—Jodgepole pine (California).*

Grinder run No.	Paper machine run No.	Ground furnish. in total	Weight per ream.	Thickness.	Mullen test.				Schopper tests.						Tintometer indications.						
					Total.	Points.	Per 0.001 in. thick- ness.	Per pound.	Horsepower per ton divided by strength factor.	Breaking length.			Stretch.		Breaking weight per sq. mm. sec- tional area.	Breaking length per horsepower per ton.	Red.	Green.	Blue.	Black.	
										Crosswise.	Lengthwise.	Average.	Crosswise.	Lengthwise.							Average.
		Per ct.	Pounds.	Inch.	Points.	Points.	Points.	Points.	Points.	Meters.	Meters.	Meters.	Per ct.	Per ct.	Per ct.	Grams.	Meters.	Parts.	Parts.	Parts.	Parts.
1	236	80	33	0.0031	18.4	6.0	0.56	222	2,530	5,620	4,080	1.78	1.38	1.58	2,120	32.8	45	28	21	206	
2	213	80	32	.0041	12.2	3.0	.38	362	2,760	5,180	3,970	1.46	.90	1.18	1,630	28.9	72	62	56	110	
3	360	80	34	.0042	15.0	3.6	.44	527	2,950	6,100	4,520	1.96	1.30	1.63	1,920	19.5	78	69	61	92	
10	361	80	35	.0040	17.6	4.4	.50	428	2,850	5,550	4,200	3.32	1.82	2.57	1,910	19.6	76	67	59	98	
11	362	80	36	.0043	15.3	3.6	.42	593	2,490	5,140	3,820	2.36	1.60	1.98	1,690	16.5	77	65	57	101	
12	371	80	36	.0043	14.2	3.3	.39	534	2,240	4,620	3,430	2.38	1.60	1.99	1,500	15.3	62	52	46	140	
13	363	80	36	.0044	17.2	3.9	.45	555	2,700	5,180	3,940	2.84	1.52	2.18	1,760	15.8	83	73	64	80	
14	323	80	32	.0030	11.3	3.7	.36	448	2,030	4,550	3,790	1.58	1.10	1.34	1,680	17.3	67	60	53	93	
15	369	82	35	.0044	12.8	2.9	.37	362	2,580	4,710	3,640	2.28	1.48	1.88	1,540	27.2	78	68	58	96	
16	387	84	31	.0038	11.8	3.1	.38	309	2,370	4,370	3,580	1.56	.78	1.17	1,520	30.5	84	74	59	83	
17	376	80	34	.0044	12.0	2.7	.35	332	2,200	4,220	3,210	2.00	1.58	1.79	1,280	27.7	80	70	60	90	
18	433	80	34	.0039	16.1	4.1	.47	509	2,840	5,740	4,290	2.02	1.06	1.49	2,030	27.9	80	70	60	90	
19	434	80	32	.0038	13.6	3.6	.42	468	2,840	5,510	4,180	2.02	.96	1.49	1,920	21.3	74	60	55	111	
20	435	80	31	.0038	12.4	3.3	.40	349	2,800	5,400	4,100	1.46	.92	1.19	1,790	29.4	70	62	57	115	
21	cml. 7	75	34	.0034	7.4	2.2	.22	352	1,450	2,740	2,100	1.32	.80	1.06	1,320	27.1	62	57	57	124	
26	450	80	34	.0050	9.6	1.9	.28	277	2,230	3,750	2,990	1.68	.94	1.31	1,120	38.6	75	62	55	108	

NOTE.—For runs 22 to 25, inclusive, see Mixture of woods.

GROUND-WOOD PULP.

TABLE 46.—*Quality tests—western yellow pine.*

Grinder run No.	Paper machine run No.	Ground wood in total furnish.	Weight per ream.	Thickness.	Mullen test.				Schopper tests.						Tintometer indications.				
					Total.	Per 0.001 inch of thickness.	Per pound.	Horsepower per ton divided by strength factor.	Breaking length.			Stretch.		Breaking weight per square millimeter sectional area.	Breaking length per horsepower	Red.	Green.	Blue.	Black.
									Crosswise.	Lengthwise.	Average.	Per ct.	Lengthwise.							Average.
1	102	79	35	11.4	3.61	0.326	282	2,296	3,456	2,876	1.36	0.68	1.02	1,878	31.3	79	57	49	115
2	106	80	34	11.9	2.34	0.350	218	2,240	3,770	3,005	1.16	0.90	1.03	1,250	39.4	84	70	62	84
3	5	80	34	11.5	2.59	0.328	226	1,778	4,583	3,181	1.01	1.05	1.03	1,375	43	81	61	53	105
4	223	80	35	11.3	2.3	0.32	324	2,340	4,400	3,370	1.86	1.28	1.57	1,340	32.5	79	67	59	95
8	300	100	47	28.6	6.5	0.61	247	3,560	6,000	4,780	2.46	1.58	2.02	2,990	36.9	51	34	25	190
9	271	100	33	16.2	5.23	0.49	226	2,870	5,300	4,080	1.76	1.30	1.53	2,350	36.9	50	34	24	200
10	273	100	46	25.0	5.0	0.54	223	2,970	5,620	4,360	1.86	1.36	1.62	2,680	36.3	48	30	22	120
11	319	100	35	15.4	4.2	0.44	719	2,970	5,540	4,260	1.84	1.40	1.62	2,260	13.5	72	59	49	92
12	347	80	36	13.5	3.3	0.35	293	2,950	4,830	3,890	1.94	1.22	1.58	1,630	38	80	68	59	93
13	351	80	34	13.5	3.1	0.40	346	2,660	5,080	3,870	1.78	1.18	1.48	1,560	28	81	69	58	92
14	349	80	34	11.4	2.5	0.33	424	2,500	4,460	3,480	1.92	1.18	1.55	1,350	24.8	81	68	57	94
15	350	80	34	12.5	2.7	0.37	364	2,690	5,380	4,140	1.60	0.88	1.24	1,460	20.8	81	67	55	97
16	408	80	37	14.6	3.0	0.40	286	2,890	5,380	4,140	1.56	1.04	1.30	1,820	36.2	76	64	55	105
17	422	80	37	11.2	2.4	0.30	271	2,420	4,060	3,240	1.56	0.98	1.24	1,400	39.9	76	64	55	105
18	409	80	32	8.0	1.7	0.25	263	2,180	3,330	2,760	1.00	0.66	0.83	1,060	41.9	77	65	56	102
19	423	80	41	11.2	2.0	0.27	233	2,070	3,680	2,880	1.40	0.98	1.19	1,200	45.8	77	63	54	106
27	15	75	32	5.4	1.6	0.17	379	1,150	2,710	1,930	0.78	0.42	0.76	1,040	29.9	61	56	56	127
27	448	80	36	9.4	2.0	0.26	248	2,050	3,500	2,780	1.92	0.92	1.42	1,150	43.1	74	62	51	113

1 Commercial.

NOTE.—For runs 20 to 26, inclusive, see Mixture of woods.

TABLE 47.—Quality tests—jack pine.

Grinder run No.		Paper machine run No.		Ground wood in total furnish.		Weight per ream.		Thickness.		Mullen test.				Schopper tests.						Tintometer indications.			
		Per ct.	Pounds.	Inch.	Points.	Total.	Points.	Per 0.001 in. thickness.	Points.	Per pound.	Horsepower per ton divided by strength factor.	Breaking length.			Stretch.		Breaking weight per sq. mm. sectional area.	Breaking length per horsepower	Red.	Green.	Blue.	Black.	
												Crosswise.	Lengthwise.	Average.	Crosswise.	Lengthwise.							Average.
25	120	80	31	0.0045	18.4	1.89	0.271	267	2,272	3,000	2,636	1.28	0.74	1.01	963	36.4	87	72	65	76			
26	231	80	34	.0036	14.6	4.0	.13	258	2,180	4,530	3,360	1.92	1.30	1.61	1,620	30.4	50	34	26	190			
27	214	80	34	.0047	11.8	2.5	.35	427	2,340	4,710	3,530	2.24	1.12	1.68	1,420	23.6	76	64	57	103			
28	276	100	45	.0042	22.5	5.3	.30	296	3,140	4,860	4,000	2.28	1.26	1.77	2,340	27.1	48	36	22	200			
29	285	100	49	.0048	22.8	4.8	.46	265	2,900	5,480	4,190	2.08	1.56	1.82	2,400	34.3	51	33	24	192			
30	287	100	43	.0044	20.3	4.6	.47	250	2,680	5,030	3,860	2.06	1.66	1.81	2,200	32.9	48	30	23	199			
31	269	100	40	.0038	18.2	4.9	.46	264	2,770	4,940	3,860	2.16	1.28	1.72	2,180	31.8	46	28	20	206			
32	301	100	47	.0050	21.0	4.2	.45	545	3,280	5,390	4,340	2.40	1.36	1.88	2,360	17.7	65	50	38	147			
33	298	100	37	.0042	13.0	3.1	.35	251	2,180	3,580	2,880	1.70	1.48	1.59	1,440	32.8	48	31	24	197			

TABLE 48.—Quality tests—loblolly pine.
FALL-CUT WOOD.

Grinder run No.	Paper machine run No.	Ground wood in total furnish.	Weight per ream.	Thickness.	Mullen test.				Schopper tests.						Tintometer indications.					
					Total.	Points.	Per 0.001 in. thickness.	Per pound.	Horsepower per ton divided by strength factor.	Breaking length.			Stretch.		Breaking weight per sq. mm. sec.	Breaking length per horsepower.	Red.	Green.	Blue.	Black.
										Crosswise.	Lengthwise.	Average.	Crosswise.	Lengthwise.							Average.
1	611	80	40	0.0050	11.0	2.2	0.26	330	2,150	3,840	3,000	1.62	0.90	1.26	1,420	32.4	81	70	61	Paris.
2	610	80	42	0.0052	11.1	2.1	0.25	314	2,180	3,815	2,750	1.58	0.84	1.17	1,330	33.7	80	71	61	Paris.
3	612	80	44	0.0050	13.2	3.0	0.35	329	2,320	4,720	3,520	1.92	1.26	1.59	1,840	30.6	73	65	59	Paris.
4	616	80	45	0.0054	16.0	3.0	0.35	300	2,550	4,040	3,300	1.94	1.06	1.51	1,600	25.5	82	73	64	Paris.
5	614	80	40	0.0047	16.2	3.4	0.41	474	2,620	5,310	3,960	1.92	1.06	1.49	2,020	20.4	84	72	65	Paris.
6	613	80	40	0.0052	14.3	2.8	0.34	276	2,525	3,950	3,240	1.78	0.96	1.37	1,610	34.5	75	65	58	Paris.
7	618	80	40	0.0049	10.6	2.2	0.26	362	2,100	4,130	3,120	1.42	0.94	1.18	1,390	33.1	76	65	59	Paris.
8	614	80	40	0.0049	10.8	2.5	0.29	325	2,320	4,090	3,200	1.46	0.96	1.21	1,590	34.0	74	65	59	Paris.
9	614	80	37	0.0043	20.4	4.7	0.42	278	2,780	4,890	3,850	1.64	0.84	1.24	2,570	32.8	42	30	25	Paris.
10	614	80	37	0.0042	20.4	2.4	0.28	396	2,170	4,040	3,100	1.54	0.86	1.45	1,470	28.7	70	62	63	Paris.
11	632	80	33	0.0042	7.3	1.7	0.22	415	1,940	3,620	2,780	1.48	0.92	1.20	1,120	32.6	80	71	62	Paris.
12	631	80	33	0.0049	9.9	2.0	0.25	328	1,940	3,620	2,880	1.54	0.92	1.20	1,240	32.6	80	71	62	Paris.
13	631	80	37	0.0050	9.2	1.8	0.25	353	1,930	3,830	2,880	1.22	0.94	1.08	1,340	32.6	74	68	69	Paris.
14	636	80	38	0.0050	8.2	1.6	0.22	325	1,910	3,320	2,620	1.28	0.82	1.05	1,000	36.6	78	69	61	Paris.

SPRING-CUT WOOD.																				
3	609	80	40	0.0045	14.1	3.1	0.35	396	2,590	4,920	3,760	1.68	1.12	1.40	1,990	27.2	71	61	55	Paris.
4	608	80	38	0.0047	11.0	2.3	0.29	425	2,270	4,300	3,285	1.54	0.90	1.22	1,585	28.6	70	60	54	Paris.
5	613	80	39	0.0047	12.2	2.6	0.31	350	2,360	4,220	3,290	1.66	1.04	1.35	1,610	30.3	74	64	57	Paris.
6	615	80	41	0.0046	15.2	3.3	0.37	354	2,810	4,530	3,670	2.10	1.12	1.61	2,040	28.0	72	61	54	Paris.
7	617	80	39	0.0045	13.5	3.0	0.35	411	2,790	4,700	3,740	1.68	0.88	1.28	1,840	26.0	73	62	55	Paris.
8	606	80	38	0.0040	12.0	3.0	0.35	502	2,390	5,090	3,640	1.28	0.92	1.10	1,800	20.7	73	65	56	Paris.
9	627	80	27	0.0035	19.2	2.6	0.34	515	2,395	4,885	3,640	1.28	0.80	1.04	1,730	20.8	68	58	52	Paris.
10	597	80	48	0.0042	21.9	5.3	0.48	263	3,110	5,650	4,380	1.80	1.00	1.43	3,040	36.2	39	31	25	Paris.
11	599	100	48	0.0041	23.0	5.6	0.48	248	2,720	6,080	4,400	2.00	1.24	1.62	3,030	37.0	39	31	26	Paris.
12	601	100	58	0.0053	26.5	5.0	0.46	230	3,000	5,610	4,310	1.82	1.06	1.47	2,840	40.7	43	31	26	Paris.
13	600	100	48	0.0040	18.8	4.7	0.45	271	3,000	4,940	4,000	1.30	1.14	1.19	2,540	29.7	51	33	33	Paris.
14	602	100	50	0.0040	18.8	3.0	0.28	298	2,500	4,240	3,270	1.62	1.34	1.48	1,900	38.7	62	54	47	Paris.
15	638	80	38	0.0050	8.0	1.6	0.21	328	1,770	3,560	2,660	1.50	0.86	1.18	1,550	38.7	72	61	53	Paris.
16	618	80	42	0.0054	13.2	2.4	0.31	338	3,020	5,700	4,390	1.24	1.04	1.14	1,480	41.9	78	67	60	Paris.
17	637	80	45	0.0057	13.8	2.4	0.30	340	2,330	4,350	3,550	1.54	1.04	1.29	1,480	32.8	82	72	64	Paris.
18	619	80	45	0.0053	15.6	2.9	0.35	305	2,800	4,210	3,500	1.80	0.92	1.39	1,710	33.8	73	63	58	Paris.

SPRING-CUT WOOD.

3	609	80	40	0.0045	14.1	3.1	2.3	0.35	396	2,590	4,920	1.68	1.12	1,990	27.2	71	55	113
4	608	80	38	0.0047	11.0	2.6	3.0	0.29	425	2,270	4,300	1.54	0.90	1,385	26.6	70	54	116
5	613	80	39	0.0047	12.2	2.6	3.3	0.31	350	2,360	4,220	1.66	1.04	1,505	30.3	64	51	102
6	615	80	41	0.0046	15.2	3.0	3.5	0.37	354	2,810	4,530	2.10	1.12	2,040	28.0	72	61	94
7	617	80	39	0.0045	13.5	3.0	3.0	0.35	411	2,790	3,740	1.68	0.88	1,840	26.0	73	65	106
8	617	80	33	0.0040	12.0	3.0	3.6	0.36	502	2,350	5,090	1.78	0.92	1,800	20.7	73	65	106
9	607	80	27	0.0035	19.2	2.6	2.6	0.34	515	2,395	4,885	1.28	0.80	1,730	30.2	68	58	122
10	597	100	48	0.0042	21.9	5.3	5.3	0.46	263	3,110	5,650	1.86	1.00	1,430	26.8	39	30	206
11	599	100	48	0.0041	23.0	5.6	5.6	0.46	248	2,720	6,080	2.00	1.24	3,030	37.0	41	31	202
12	600	100	58	0.0053	26.5	5.0	5.0	0.48	280	3,060	5,610	1.80	1.14	3,030	40.7	43	26	200
13	601	100	50	0.0064	18.8	4.7	4.7	0.45	271	3,060	4,940	1.32	1.06	2,840	32.8	51	40	176
14	602	100	42	0.0040	18.8	3.0	3.8	0.38	298	2,500	4,240	1.02	1.34	1,540	29.7	62	47	137
15	602	100	50	0.0050	8.0	1.6	1.6	0.21	328	3,170	5,700	1.50	0.86	1,180	38.7	70	61	116
16	618	80	38	0.0050	13.2	2.4	2.4	0.31	338	3,020	5,700	1.24	1.14	1,550	41.9	67	53	95
17	637	80	45	0.0057	13.8	2.4	2.4	0.30	340	2,250	4,750	1.54	1.04	1,480	34.8	72	62	112
18	619	80	45	0.0053	15.6	2.9	2.9	0.35	305	2,800	4,210	1.86	0.92	1,710	32.8	73	63	106

NOTE.—Pulp for No. 29 was made on a coarse-grit stone.

TABLE 49.—*Quality tests—white pine.*

Grinder run No.	Paper machine run No.	Ground wood in total	Weight per ream.	Thickness.	Mullen test.				Horsepower per ton divided by strength factor.	Schopper tests.						Tintometer indications.					
					Total.	Points.	Per 0.001 in. thickness.	Per pound.		Breaking length.			Stretch.		Breaking weight per sq. mm. sectional area.	Breaking length per horsepower	Red.	Green.	Blue.	Black.	
										Crosswise.	Lengthwise.	Average.	Crosswise.	Lengthwise.							Average.
1	497	80	37	0.0039	14.7	3.8	3.8	0.40	305	2,380	4,620	3,500	2.42	1.22	1.82	1,810	28.7	76	66	60	98
2	501	80	37	.0044	13.0	3.0	3.0	.35	288	2,070	4,090	3,080	2.38	1.14	1.76	1,560	30.5	77	67	60	96
3	502	80	36	.0043	12.6	2.9	2.9	.35	257	2,120	4,010	3,080	2.18	1.16	1.67	1,530	34.0	79	70	64	87
4	503	80	38	.0046	11.2	2.5	2.5	.30	256	1,940	3,760	2,850	2.12	1.16	1.64	1,400	37.0	79	70	64	88
5	498	80	37	.0042	17.3	4.1	4.1	.47	293	2,280	4,890	3,580	2.12	1.12	1.62	1,790	32.2	77	67	61	95
6	504	80	34	.0040	13.3	3.4	3.4	.39	266	2,070	4,620	3,340	2.24	1.16	1.70	1,660	32.2	79	71	64	86
7	499	80	37	.0043	14.2	3.3	3.3	.38	283	2,230	4,290	3,260	2.06	1.22	1.64	1,610	33.2	79	69	62	90
8	500	80	38	.0044	12.8	2.9	2.9	.34	281	1,880	3,770	2,820	2.18	1.10	1.64	1,410	29.6	78	69	63	90
9	564	100	36	.0034	18.2	3.3	3.3	.50	239	2,270	4,760	3,520	2.50	1.84	1.67	2,260	27.1	57	43	36	164
10	561	100	35	.0034	17.6	3.2	3.2	.50	222	2,220	5,210	3,720	2.88	1.87	2.08	2,320	33.5	59	45	38	158
11	562	100	40	.0039	19.6	3.2	3.2	.49	221	2,310	5,260	3,780	3.76	1.58	2.67	2,320	34.8	59	43	36	162
12	563	100	36	.0035	14.8	4.2	4.2	.41	270	2,140	4,510	3,320	3.68	1.20	2.44	1,980	30.0	59	44	38	159

TABLE 50.—Quality tests—Englemann spruce (Montana).

Grinder run No.	Paper machine run No.	Ground wood in total furnish.	Weight per ream.	Thickness.	Mullen test.				Schopper tests.						Tintometer indications.				
					Total.	Per 0.001 in. thick-ness.	Per pound.	Horsepower per ton divided by strength factor.	Breaking length.			Stretch.		Breaking weight per sq. mm. sec- tional area.	Breaking length per horsepower	Red.	Green.	Blue.	Black.
									Crosswise.	Lengthwise.	Average.	Crosswise.	Lengthwise.							Average.
1	565	80	37	0.0041	12.8	3.1	0.35	226	2,350	4,160	3,260	1.64	1.00	1.32	71	79	64	86	Parts.
2	566	80	35	0.0040	10.0	2.5	.29	229	2,110	3,790	3,070	1.28	1.06	1.05	84	84	65	77	Parts.
3	568	80	38	0.0044	10.6	2.4	.28	242	2,110	3,790	3,070	1.72	1.04	1.38	74	82	74	79	Parts.
4	570	80	27	0.0034	7.1	2.1	.26	248	2,090	3,660	2,880	1.24	.74	1.99	66	79	66	77	Parts.
5	573	80	32	0.0039	8.7	2.2	.27	252	2,320	3,710	3,020	1.26	.82	1.04	74	82	70	87	Parts.
6	567	80	33	0.0038	11.2	2.9	.34	198	2,530	4,540	3,540	2.20	1.0	1.04	64	79	64	79	Parts.
7	569	80	35	0.0042	9.7	2.3	.28	187	2,210	3,550	2,880	1.74	.86	1.30	67	84	74	75	Parts.
8	554	100	33	0.0028	21.5	7.7	.65	121	3,160	6,260	4,710	2.48	.92	1.70	32	49	36	73	Parts.
9	555	100	37	0.0034	22.9	6.6	.62	128	3,030	6,280	4,600	3.16	1.30	2.23	44	55	42	83	Parts.
10	556	100	41	0.0039	23.5	6.0	.57	125	2,770	5,730	4,250	2.62	1.04	1.83	47	59	47	168	Parts.
11	571	80	36	0.0044	10.8	2.5	.30	220	2,430	4,160	3,150	1.38	.92	1.15	59	77	60	94	Parts.
12	572	80	33	0.0038	10.0	2.6	.30	195	2,430	4,360	3,400	1.52	.86	1.19	47	69	60	75	Parts.
13	574	80	36	0.0043	10.9	2.5	.30	193	2,440	4,180	3,310	1.40	.92	1.16	77	83	75	72	Parts.
14	667	80	29	0.0033	8.9	2.7	.31	277	2,950	4,780	3,800	1.18	.78	.98	69	84	75	69	Parts.
15	673	80	45	0.0047	13.7	3.3	.35	210	2,890	5,150	4,020	1.94	1.02	1.48	60	71	65	104	Parts.
16	675	80	41	0.0046	14.5	3.1	.35	185	2,850	5,280	4,060	1.82	1.00	1.41	67	80	72	81	Parts.
17	674	80	38	0.0043	13.2	3.1	.35	211	2,850	5,110	3,980	2.14	.98	1.56	72	82	77	71	Parts.
18	669	80	40	0.0047	14.3	3.0	.36	213	2,620	5,130	3,880	1.56	.92	1.24	63	79	72	86	Parts.
19	677	80	36	0.0043	10.5	2.4	.29	235	2,540	4,640	3,590	1.42	.86	1.14	73	81	75	90	Parts.

TABLE 51. — *Quality tests—Engelmann spruce (Colorado).*

Grinder run No.	Paper machine run No.	Ground wood in total furnish.	Weight per ream.	Thickness.	Mullen test.				Schopper tests.				Tintometer indications.			
					Total.	Per 0.001 in. thickness.	Per pound.	Horsepower per ton divided by strength factor.								
				Inch.	Points.	Points.	Points.		Breaking lengthwise.	Average.	Crosswise.	Lengthwise.	Average.	Breaking weight per sq. mm. sec.	Breaking length per ton.	
		Per ct.	Pounds.						Meters.		Per ct.	Per ct.		Grams.	Meters.	Parts.
1	466	80	35	0.0039	15.6	4.0	0.45	246	2,880	5,590	4,140	1.18	1.59	2,190	37.4	75
2	467	80	30	0.0034	10.2	3.0	0.34	267	2,500	4,360	3,460	1.14	1.63	1,830	37.2	62
3	468	80	35	0.0040	11.8	3.0	0.34	251	2,580	4,080	3,460	1.03	1.43	1,890	42.5	79
4	740	80	37	0.0044	10.7	2.5	0.29	346	2,150	4,630	3,390	1.78	1.14	1,900	38.9	67
5	469	80	31	0.0040	9.0	2.3	0.29	266	2,400	4,050	3,260	1.36	1.33	1,540	42.1	60
6	470	80	32	0.0036	10.2	2.7	0.32	252	2,460	4,450	3,460	1.06	1.02	1,710	42.8	81
7	471	80	31	0.0036	9.2	2.6	0.30	260	2,500	4,070	3,280	1.58	1.32	1,610	42.0	74
8	472	80	32	0.0038	10.6	2.8	0.33	230	2,510	4,200	3,360	1.04	1.34	1,660	44.1	81
9	515	80	36	0.0042	13.2	3.1	0.27	335	2,290	4,890	3,590	1.96	1.52	1,870	39.7	79
10	516	80	35	0.0040	11.4	2.9	0.33	226	2,140	4,230	3,180	1.02	1.48	1,630	42.6	64
11	517	80	35	0.0043	12.1	2.8	0.35	204	2,380	4,330	3,360	1.56	1.92	1,580	47.0	82
12	518	80	36	0.0045	10.7	2.4	0.30	223	2,170	3,920	3,400	1.78	1.24	1,440	45.4	75
13	538	100	48	0.0040	34.4	8.7	0.72	154	2,720	6,150	4,440	3.56	2.30	3,200	40.0	84
14	539	100	40	0.0033	26.2	8.0	0.66	147	2,750	5,540	4,140	3.56	2.31	3,020	42.5	55
15	540	100	37	0.0031	22.6	7.2	0.61	155	2,700	5,030	4,270	2.64	1.12	2,850	45.0	31
16	541	100	41	0.0039	23.3	6.0	0.57	160	2,310	5,930	4,120	2.14	1.88	2,830	45.1	35
17	524	100	45	0.0039	31.4	8.1	0.70	140	3,220	7,410	5,320	2.62	1.55	3,060	45.4	30
18	525	100	46	0.0045	25.8	5.8	0.56	154	2,770	5,000	2,14	1.10	1.86	3,000	54.4	41
19	116	80	36	0.0032	9.3	2.9	0.28	292	1,580	2,630	2,110	1.12	1.92	1,480	27.8	60
19	650	80	32	0.0040	9.7	2.4	0.30	253	2,140	4,450	3,310	.92	1.27	1,370	43.5	76

1 Commercial.

TABLE 52.—Quality tests—Sitka spruce.

Grinder run No.	Paper machine run No.	Ground wood in total furnish.	Weight per ream.	Thickness.	Mullen test.				Schopper tests.						Tintometer indications.					
					Total.	Per 0.001 in. thickness.	Per pound.	Horsepower per ton divided by strength factor.	Breaking length.			Stretch.		Breaking weight per sq. mm. sec.	Breaking length per horsepower.	Red.	Green.	Blue.	Black.	
									Crosswise.	Lengthwise.	Average.	Crosswise.	Lengthwise.							Average.
Points.	Points.	Points.	Per cent.	Parts.	Parts.	Parts.	Parts.	Parts.	Parts.	Parts.	Parts.	Parts.	Parts.	Parts.	Parts.	Parts.	Parts.			
211	211	80	30	0.0034	13.4	4.0	0.45	262	2,950	5,400	4,170	2.24	1.14	1.69	1,990	35.4	66	58	123	
263	263	100	51	.0044	28.6	6.5	.56	234	3,070	6,000	4,540	2.66	1.58	2.12	2,940	34.6	44	28	206	
264	264	100	51	.0041	33.8	8.2	.66	195	3,120	6,700	4,910	2.26	1.44	1.85	3,280	38.1	38	23	221	
265	265	100	42	.0034	24.2	7.0	.58	195	3,380	6,850	5,120	2.10	1.46	1.78	3,380	45.1	35	21	16	
365	365	80	35	.0037	17.8	4.8	.51	246	2,930	5,400	4,160	3.32	1.56	2.44	2,040	33.2	77	65	101	
366	366	80	39	.0041	18.1	4.4	.46	244	3,040	5,610	4,320	2.38	1.54	1.96	2,070	38.5	74	63	107	
367	367	80	36	.0038	16.2	4.3	.45	240	2,860	5,240	4,050	2.74	1.44	2.09	1,960	37.5	72	62	110	
368	368	80	39	.0043	17.0	4.0	.44	239	2,640	5,010	3,820	3.06	1.56	2.31	1,850	36.4	72	61	112	
388	388	80	36	.0036	18.3	3.5	.51	415	2,360	6,140	4,750	2.02	1.18	1.60	2,480	22.4	66	54	130	
389	389	80	38	.0038	20.2	5.3	.33	294	2,490	6,120	4,800	2.34	1.12	1.73	2,560	30.8	71	60	136	
370	370	80	33	.0035	16.2	4.6	.49	286	3,020	5,720	4,370	2.60	1.42	2.03	2,090	31.2	68	57	124	
343	343	80	36	.0038	15.4	4.1	.43	335	3,200	5,700	4,480	1.86	1.26	1.86	2,250	31.1	71	59	130	
324	324	81	32	.0032	15.4	4.9	.48	779	2,800	5,160	4,180	2.44	1.72	2.08	2,240	11.2	60	50	147	
295	295	100	48	.0037	27.2	7.3	.56	429	3,190	6,100	4,350	2.76	1.76	2.26	3,400	19.5	35	21	16	
325	325	80	26	.0027	10.6	3.9	.41	976	3,190	5,510	4,350	2.36	1.62	1.99	2,300	10.9	64	52	139	
13	13	75	40	.0034	9.8	2.9	.25	408	1,450	3,640	2,540	1.24	.98	1.11	1,720	24.9	65	60	115	
446	446	80	33	.0040	12.6	3.2	.38	268	2,640	4,610	3,620	2.44	1.16	1.80	1,600	35.5	73	61	116	

1 Commercial.

TABLE 53.—*Quality tests—white birch.*

Grinder run No.	Paper machine run No.	Ground wood in to-tal furnish.	Weight per ream.	Mullen test.				Schopper tests.				Tintometer indications.							
				Thickness.	Total.	Per 0.001 in. thickness.	Per pound.	Horsepower per ton divided by strength factor.	Breaking length.		Stretch.		Breking length per horsepow-er per ton.	Red.	Green.	Blue.	Black.		
									Crosswise.	Lengthwise.	Average.	Crosswise.						Lengthwise.	Average.
			Pounds.	Inch.	Points.	Points.	Point.		Meters.	Meters.	Per ct.	Per ct.	Per ct.	Grams.	Meters.	Parts.	Parts.	Parts.	Parts.
1	237	80	32	0.0029	15.8	5.5	0.49	135	2,470	5,130	3,800	1.52	1.12	1,121	57.4	34	20	16	230
2	216	80	33	0.0046	6.4	1.4	0.19	596	1,660	2,630	2,140	1.34	0.94	840	18.9	74	63	58	105
3	322	100	48	0.0042	24.7	5.8	0.51	150	2,580	4,600	3,590	2.96	1.26	2,310	46.7	36	22	16	226
4	278	100	52	0.0049	24.0	4.9	0.46	155	2,730	3,800	3,260	2.24	1.30	1,990	45.8	38	24	19	219
5	274	100	57	0.0053	27.8	5.2	0.49	152	2,950	4,880	3,920	2.72	1.24	2,300	52.5	39	24	19	218
6	427	80	34	0.0046	9.8	2.1	0.29	667	2,190	3,770	3,030	1.58	0.92	1,280	15.7	69	59	54	118
7	425	80	34	0.0046	8.6	1.9	0.25	629	2,010	3,540	2,780	1.44	0.76	1,110	17.7	66	56	60	118
8	426	80	35	0.0049	8.7	1.8	0.25	519	2,110	3,520	2,820	1.02	0.64	1,160	21.0	66	55	47	132
9	428	80	34	0.0049	7.4	1.5	0.22	512	1,810	2,900	2,360	1.10	0.64	930	21.8	73	60	53	114

TABLE 54.—*Quality tests—aspens.*

Grinder run No.	Paper machine run No.	Ground wood in to- tal furnish.	Weight per ream.	Mullen test.			Schopper tests.				Tintometer indications.							
				Thickness.	Total.	Per 0.001 in. thickness.	Per pound.	Horsepower per ton divided by strength factor.	Breaking length.		Stretch.		Red.	Green.	Blue.	Black.		
									Inch.	Points.	Points.	Points.					Per c.	Parts.
1	234	80	32	0.0028	12.8	4.6	0.40	158	2,080	4,130	3,110	1.66	1.24	1.45	44	30	23	203
2	217	80	33	0.0042	9.8	2.3	0.30	464	2,240	3,880	3,060	1.70	1.10	1.40	73	63	56	108
3	262	100	61	0.0049	28.2	5.7	0.46	131	2,810	4,960	3,880	3.06	1.30	2.18	37	23	18	222
4	261	100	55	0.0045	29.9	6.6	0.54	138	3,290	5,850	4,570	2.72	1.32	2.02	36	23	18	223
5	260	100	63	0.0052	32.2	6.2	0.51	118	2,970	5,240	4,100	2.94	1.32	2.13	38	23	18	221
6	436	80	31	0.0039	11.0	2.8	0.36	870	2,760	4,970	3,860	1.48	1.16	1.46	72	64	56	108
7	437	80	29	0.0038	9.2	2.4	0.32	680	2,460	4,120	3,290	1.20	0.84	1.00	73	63	56	108
8	438	80	28	0.0038	8.4	2.2	0.30	606	2,440	4,250	3,340	1.24	0.78	1.01	69	62	54	115
9	439	80	34	0.0045	9.8	2.2	0.29	559	2,240	3,500	2,870	1.58	0.80	1.19	76	66	57	101
10	440	80	35	0.0040	14.2	3.6	0.41	1,040	2,690	4,870	3,780	1.52	1.04	1.28	72	60	50	118
11	441	80	32	0.0039	12.0	3.1	0.38	781	2,740	4,640	3,690	1.94	0.98	1.46	73	60	53	114
12	442	80	33	0.0041	12.2	3.0	0.37	625	2,660	4,270	3,460	1.86	1.06	1.50	73	67	49	111
13	443	80	32	0.0041	10.9	2.7	0.34	509	2,640	4,490	3,560	1.48	0.80	1.14	73	61	52	114

TABLE 55.—Quality tests—black gum.

Grinder run No.	Paper machine run No.	Ground wood in total furnish.	Weight per ream.	Thickness.	Mullen test.				Schopper tests.						Tintometer indications.						
					Total.	Points.	Per 0.001 in. thickness.	Per pound.	Horsepower per ton divided by strength factor.	Breaking length.			Stretch.			Breaking weight per sq. mm. sectional area.	Breaking length per horsepower.	Red.	Green.	Blue.	Black.
										Crosswise.	Lengthwise.	Average.	Crosswise.	Lengthwise.	Average.						
1	727	80	34	0.0043	10.3	2.4	0.30	870	2,190	5,130	3,660	1.18	1.00	1.09	1,520	14.0	76	68	64	92	
2	732	80	35	0.0045	9.7	2.2	0.28	818	1,800	4,270	3,040	1.16	1.16	1.29	1,290	13.3	80	71	65	84	
3	728	80	35	0.0046	8.6	1.8	0.25	567	1,860	3,950	2,900	1.38	1.00	1.19	1,160	20.5	80	72	66	82	
4	629	80	37	0.0052	9.5	1.8	0.26	658	1,760	3,280	2,520	1.64	0.86	1.25	1,090	14.7	81	74	70	75	
5	738	80	33	0.0048	8.6	1.8	0.26	667	1,680	3,830	2,760	1.28	0.96	1.12	1,040	15.9	76	66	64	94	
6	631	80	43	0.0055	10.8	2.0	0.23	787	2,080	3,880	2,980	1.84	1.06	1.45	1,250	16.5	77	71	66	86	
7	630	80	41	0.0056	8.9	1.6	0.22	777	1,540	3,000	2,270	1.56	0.96	1.26	960	13.3	81	72	68	79	
8	628	80	47	0.0067	7.6	1.1	0.16	465	1,210	2,110	1,660	1.34	0.84	1.09	710	22.3	85	74	67	74	
9	668	100	42	0.0056	7.4	1.2	0.18	401	1,410	2,460	1,940	1.22	0.86	1.04	840	26.8	88	56	50	126	
10	663	100	48	0.0049	21.2	4.4	0.44	190	2,370	5,240	3,920	1.86	1.40	1.63	2,260	47.0	45	33	31	191	
11	695	100	43	0.0043	18.0	4.2	0.42	229	2,460	5,240	3,850	2.08	1.14	1.61	2,300	40.0	49	37	32	182	
12	694	100	53	0.0054	20.9	3.9	0.39	207	2,560	4,880	3,720	2.58	1.42	2.00	2,050	46.1	50	38	33	179	
13	656	80	44	0.0060	6.5	1.1	0.15	545	1,370	2,440	1,900	1.08	0.80	0.99	780	23.2	77	68	64	91	
14	711	80	47	0.0066	5.1	0.8	0.11	644	1,980	1,820	1,400	1.00	0.66	0.83	550	19.8	82	73	67	78	

NOTE.—Pulp for No. 14 was made on a coarse-grit stone.

TABLE 56.—*Quality tests.*

MIXTURE OF WOODS.

Grinder run No.	Paper machine run No.	Ground wood in total furnish.	Weight per ream.	Thickness.	Mullen test.				Schopper tests.				Tintometer indications.							
					Total.	Points.	Per 0.001 in. thickness.	Per pound.	Horsepower per ton divided by strength factor.	Breaking length.			Stretch.		Breaking weight per sq. mm. sectional area.	Breaking length per horsepower.	Red.	Green.	Blue.	Black.
										Crosswise.	Lengthwise.	Average.	Crosswise.	Lengthwise.							Average.	Per ct.	Per ct.
50	312	100	42	0.0040	17.4	4.4	0.41	227	2,580	4,780	3,680	2.62	1.44	2.03	2,210	39.4	39	23	16	Parts.
51	314	100	42	.0039	16.5	4.2	.39	273	2,360	4,560	3,460	2.28	1.58	1.93	2,060	32.5	42	44	17	Parts.
52	313	100	49	.0044	19.6	4.4	.40	254	2,640	5,020	3,830	3.08	1.50	2.29	2,330	37.8	38	22	15	Parts.
WESTERN YELLOW PINE.																				
20	407	80	32	0.0039	13.8	3.5	0.43	227	2,980	4,850	3,920	1.72	.90	1.31	1,720	40.2	79	66	57	98
21	424	80	34	.0042	12.6	3.0	.37	272	2,650	5,230	3,940	1.48	.96	1.22	1,680	39.2	75	64	54	107
22	410	80	35	.0045	13.5	3.0	.39	267	2,730	5,060	3,920	1.56	.84	1.20	1,650	37.7	70	59	52	119
23	411	80	31	.0038	12.8	3.4	.41	262	3,000	5,260	4,130	1.46	.82	1.14	1,780	38.5	70	59	51	120
24	406	80	32	.0041	11.4	2.8	.36	330	2,440	4,270	3,360	1.52	.90	1.21	1,380	28.3	67	54	45	134
25	412	80	32	.0041	11.4	2.8	.36	321	2,740	4,280	3,520	1.76	.80	1.28	1,490	30.4	69	56	47	130
26	413	80	36	.0046	13.6	3.0	.38	300	2,770	4,970	3,870	1.68	.92	1.30	1,700	34.0	68	55	47	138
WESTERN HEMLOCK.																				
15	404	80	31	0.0035	18.2	5.2	0.59	233	3,310	5,730	4,520	2.32	1.14	1.73	2,140	33.0	65	54	48	133
16	414	80	37	.0040	19.5	4.9	.53	272	3,390	6,510	4,950	2.14	1.20	1.67	2,480	34.4	64	54	47	135
17	415	80	35	.0036	21.2	5.9	.60	247	4,040	6,620	5,330	2.26	1.02	1.64	2,710	36.0	65	55	49	131

MONTANA LODGEPOLE PINE.

24	417	80	35	0.0040	13.8	3.4	0.39	299	2,520	4,760	3,640	2.76	1.48	2.12	1,760	31.2	58	47	40	155
25	416	80	36	.0042	15.4	3.7	.43	284	2,440	4,640	3,540	2.78	1.44	2.11	1,620	29.0	65	54	47	134

CALIFORNIA LODGEPOLE PINE.

22	418	80	35	0.0041	15.5	3.8	0.44	398	3,090	5,810	4,450	1.98	1.12	1.55	2,080	25.4	67	57	49	127
23	419	80	31	.0038	12.0	3.1	.36	388	2,770	5,120	3,940	2.02	1.06	1.54	1,770	26.7	67	50	49	128
24	420	80	30	.0035	13.3	3.8	.44	400	3,160	5,860	4,510	1.70	1.00	1.35	1,960	25.7	73	61	52	114
25	421	80	35	.0038	16.6	4.4	.48	346	3,290	5,820	4,560	2.16	1.02	1.59	2,290	27.5	69	58	51	122

GREEN BALSAM.

23	110	75	33	0.0029	8.4	2.9	0.26	368	1,820	3,460	2,640	1.12	.74	.93	1,690	27.6	63	57	57	123
23	453	80	33	.0040	14.2	3.5	.43	222	2,880	4,820	3,850	1.90	1.00	1.45	1,720	40.2	83	77	66	74

HEMLOCK.

63	19	75	36	0.0031	9.8	3.2	0.27	470	1,790	3,830	2,810	1.12	.84	.98	1,860	22.1	55	50	50	145
63	452	80	34	.0039	14.5	3.7	.43	296	2,940	5,100	4,020	1.82	1.00	1.41	1,870	31.7	78	66	60	96

TAMARACK.

54	112	75	36	0.0034	9.9	2.9	0.27	327	1,860	3,560	2,710	1.14	.78	.96	1,800	30.7	59	54	54	133
54	455	80	37	.0046	13.6	3.0	.37	238	2,520	4,580	3,550	1.78	1.06	1.42	1,650	40.2	77	66	61	96

1 Commercial.

TABLE 57.—Commercial runs.

Stock No. of pulp.	Kind of wood.	Run No.	Kind of burr.	Number of pockets used.	Pressure on 14-inch cyl. indr.	Pressure per square inch	Revolutions per minute.	Peripheral speed.	Average horsepower to grinder.	Maximum horsepower to grinder.	Bone-dry pulp in 24 hours.	Horsepower per ton bone-dry pulp in 24 hours.	Solid rossed wood ground in 24 hours.	Weight per cubic foot bone-dry wood.	Average diameter of wood.	Moisture in wood.	Bone-dry pulp per 100 cubic feet solid rossed wood.	Efficiency of conversion.	Screenings per 100 cubic feet solid rossed wood bone-dry.	Average temperature of grinding.	Horsepower divided by pressure X speed.
					Lbs. per sq. in.	Lbs.		Feet per minute.			Tons	Cu. ft.	Lbs.	In.	Per cent.	Per cent.	Lbs.	Per cent.		° F.	
	Green jack pine....	14	Diamond point, cut 6 to inch	3	50	20.5	171	2,400	436	7,080	64.3						2,170	85.5		148	0.00885
	Seasoned jack pine.	14	do.	3	50	20.5	171	2,400	447	6,280	72.7						2,170	86.4		148	0.00885
	Hemlock pine.	14	Spiral, cut 10 to inch.	3	50	20.5	175	2,435	349	447	103.1	334.0	24.8				2,048	82.6		145	0.00907
	do.	14-1	do.	3	50	20.5	175	2,432	368	464	115	398.0	24.8				2,077	83.7		167	0.00740
	do.	14-1	do.	3	50	20.5	175	2,432	368	464	115	398.0	24.8				2,077	83.7		167	0.00740
	do.	14-1	do.	3	50	20.5	175	2,432	368	464	115	398.0	24.8				2,077	83.7		167	0.00740
	do.	14-1	do.	3	50	20.5	175	2,432	368	464	115	398.0	24.8				2,077	83.7		167	0.00740
	do.	14-1	do.	3	50	20.5	175	2,432	368	464	115	398.0	24.8				2,077	83.7		167	0.00740
	do.	14-1	do.	3	50	20.5	175	2,432	368	464	115	398.0	24.8				2,077	83.7		167	0.00740
	do.	14-1	do.	3	50	20.5	175	2,432	368	464	115	398.0	24.8				2,077	83.7		167	0.00740
	do.	14-1	do.	3	50	20.5	175	2,432	368	464	115	398.0	24.8				2,077	83.7		167	0.00740
	do.	14-1	do.	3	50	20.5	175	2,432	368	464	115	398.0	24.8				2,077	83.7		167	0.00740
	do.	14-1	do.	3	50	20.5	175	2,432	368	464	115	398.0	24.8				2,077	83.7		167	0.00740
	do.	14-1	do.	3	50	20.5	175	2,432	368	464	115	398.0	24.8				2,077	83.7		167	0.00740
	do.	14-1	do.	3	50	20.5	175	2,432	368	464	115	398.0	24.8				2,077	83.7		167	0.00740
	do.	14-1	do.	3	50	20.5	175	2,432	368	464	115	398.0	24.8				2,077	83.7		167	0.00740
	do.	14-1	do.	3	50	20.5	175	2,432	368	464	115	398.0	24.8				2,077	83.7		167	0.00740
	do.	14-1	do.	3	50	20.5	175	2,432	368	464	115	398.0	24.8				2,077	83.7		167	0.00740
	do.	14-1	do.	3	50	20.5	175	2,432	368	464	115	398.0	24.8				2,077	83.7		167	0.00740
	do.	14-1	do.	3	50	20.5	175	2,432	368	464	115	398.0	24.8				2,077	83.7		167	0.00740
	do.	14-1	do.	3	50	20.5	175	2,432	368	464	115	398.0	24.8				2,077	83.7		167	0.00740
	do.	14-1	do.	3	50	20.5	175	2,432	368	464	115	398.0	24.8				2,077	83.7		167	0.00740
	do.	14-1	do.	3	50	20.5	175	2,432	368	464	115	398.0	24.8				2,077	83.7		167	0.00740
	do.	14-1	do.	3	50	20.5	175	2,432	368	464	115	398.0	24.8				2,077	83.7		167	0.00740
	do.	14-1	do.	3	50	20.5	175	2,432	368	464	115	398.0	24.8				2,077	83.7		167	0.00740
	do.	14-1	do.	3	50	20.5	175	2,432	368	464	115	398.0	24.8				2,077	83.7		167	0.00740
	do.	14-1	do.	3	50	20.5	175	2,432	368	464	115	398.0	24.8				2,077	83.7		167	0.00740
	do.	14-1	do.	3	50	20.5	175	2,432	368	464	115	398.0	24.8				2,077	83.7		167	0.00740
	do.	14-1	do.	3	50	20.5	175	2,432	368	464	115	398.0	24.8				2,077	83.7		167	0.00740
	do.	14-1	do.	3	50	20.5	175	2,432	368	464	115	398.0	24.8				2,077	83.7		167	0.00740
	do.	14-1	do.	3	50	20.5	175	2,432	368	464	115	398.0	24.8				2,077	83.7		167	0.00740
	do.	14-1	do.	3	50	20.5	175	2,432	368	464	115	398.0	24.8				2,077	83.7		167	0.00740
	do.	14-1	do.	3	50	20.5	175	2,432	368	464	115	398.0	24.8				2,077	83.7		167	0.00740
	do.	14-1	do.	3	50	20.5	175	2,432	368	464	115	398.0	24.8				2,077	83.7		167	0.00740
	do.	14-1	do.	3	50	20.5	175	2,432	368	464	115	398.0	24.8				2,077	83.7		167	0.00740
	do.	14-1	do.	3	50	20.5	175	2,432	368	464	115	398.0	24.8				2,077	83.7		167	0.00740
	do.	14-1	do.	3	50	20.5	175	2,432	368	464	115	398.0	24.8				2,077	83.7		167	0.00740
	do.	14-1	do.	3	50	20.5	175	2,432	368	464	115	398.0	24.8				2,077	83.7		167	0.00740
	do.	14-1	do.	3	50	20.5	175	2,432	368	464	115	398.0	24.8				2,077	83.7		167	0.00740
	do.	14-1	do.	3	50	20.5	175	2,432	368	464	115	398.0	24.8				2,077	83.7		167	0.00740
	do.	14-1	do.	3	50	20.5	175	2,432	368	464	115	398.0	24.8				2,077	83.7		167	0.00740
	do.	14-1	do.	3	50	20.5	175	2,432	368	464	115	398.0	24.8				2,077	83.7		167	0.00740
	do.	14-1	do.	3	50	20.5	175	2,432	368	464	115	398.0	24.8				2,077	83.7		167	0.00740
	do.	14-1	do.	3	50	20.5	175	2,432	368	464	115	398.0	24.8				2,077	83.7		167	0.00740
	do.	14-1	do.	3	50	20.5	175	2,432	368	464	115	398.0	24.8				2,077	83.7		167	0.00740
	do.	14-1	do.	3	50	20.5	175	2,432	368	464	115	398.0	24.8				2,077	83.7		167	0.00740
	do.	14-1	do.	3	50	20.5	175	2,432	368	464	115	398.0	24.8				2,077	83.7		167	0.00740
	do.	14-1	do.	3	50	20.5	175	2,432	368	464	115	398.0	24.8				2,077	83.7		167	0.00740
	do.	14-1	do.	3	50	20.5	175	2,432	368	464	115	398.0	24.8				2,077	83.7		167	0.00740
	do.	14-1	do.	3	50	20.5	175	2,432	368	464	115	398.0	24.8				2,077	83.7		167	0.00740
	do.	14-1	do.	3	50	20.5	175	2,432	368	464	115	398.0	24.8				2,077	83.7		167	0.00740
	do.	14-1	do.	3	50	20.5	175	2,432	368	464	115	398.0	24.8				2,077	83.7		167	0.00740
	do.	14-1	do.	3	50	20.5	175	2,432	368	464	115	398.0	24.8				2,077	83.7		167	0.00740
	do.	14-1	do.	3	50	20.5	175	2,432	368	464	115	398.0	24.8				2,077	83.7		167	0.00740
	do.	14-1	do.	3	50	20.5	175	2,432	368	464	115	398.0	24.8				2,077	83.7		167	0.00740
	do.	14-1	do.	3	50	20.5	175	2,432	368	464	115	398.0	24.8				2,077	83.7		167	0.00740
	do.	14-1	do.	3	50	20.5	175	2,432	368	464	115	398.0	24.8				2,077	83.7		167	0.00740
	do.	14-1	do.	3	50	20.5	175	2,432	368	464	115	398.0	24.8				2,077	83.7		167	0.00740
	do.	14-1	do.	3	50	20.5	175	2,432	368	464	115	398.0	24.8				2,077	83.7		167	0.00740
	do.	14-1	do.	3	50	20.5	175	2,432	368	464	115	398.0	24.8				2,077	83.7		167	0.00740
	do.	14-1	do.	3	50	20.5	175	2,432	368	464	115	398.0	24.8				2,077	83.7		167	0.00740
	do.	14-1	do.	3	50	20.5	175	2,432	368	464	115	398.0	24.8				2,077	83.7		167	0.00740
	do.	14-1	do.	3	50	20.5	175	2,432	368	464	115	398.0	24.8				2,077	83.7		167	0.00740
	do.	14-1	do.	3	50	20.5	175	2,432	368	464	115	398.0	24.8				2,077	83.7		167	0.00740
	do.	14-1	do.	3	50	20.5	175	2,432	368	464	115	398.0	24.8				2,077	83.7		167	0.00740
	do.	14-1	do.	3	50	20.5	175	2,432	368	464	115	398.0	24.8				2,077	83.7		167	0.00740
	do.	14-1	do.	3	50	20.5	175	2,432	368	464	115	398.0	24.8				2,077	83.7		167	0.00740
	do.	14-1	do.	3	50	20.5	175	2,432	368	464	115	398.0	24.8				2,077	83.7		167	0.00740
	do.	14-1	do.	3	50	20.5	175	2,432	368	464	115	398.0	24.8				2,077	83.7		167	0.00740
	do.	14-1	do.	3	50	20.5	175	2,432	368	464	115	398.0	24.8				2,077	83.7		167	0.00740
	do.	14-1	do.	3	50	20.5	175	2,432	368	464	115	398.0	24.8				2,077	83.7		167	0.00740
	do.	14-1	do.	3	50	20.5	175	2,432	368	464	115	398.0	24.8				2,077	83.			

9	Spruce.....	63	50	20.5	225	5,069	516	5924.075	127.0	(179.0	24.93	58	33.55	2,280	92.1	12.00	177	.00820
	Hemlock.....									(179.0	24.47	58	44.50					
10	Green balsam	23	40	16.4	225	3,069	476	5424.980	95.6	(254.0	20.30	58	61.66	2,160	96.2	11.50	157	.00945
	Spruce.....									(209.0	24.93	58	33.55					
11	Tamarack.....	53	40	16.4	225	3,069	430	5054.510	95.4	(324.0	32.44	58	25.25	2,780	85.6	10.10	170	.00854
	do.....											58	25.00					
12	do.....	54	65	26.6	225	3,069	415	5034.705	88.2	(185.0	30.70	58	35.13	2,410	89.4	13.75	157	.00509
13	Spruce.....	16	50	20.5	225	3,020	393	5044.275	92.0	(442.0	21.05	(1)	34.80	1,933	91.9	14.8	151	.00636
14	Noble fir.....	13	50	20.5	225	3,020	430	5795.110	84.0	(478.0	21.80	78	43.00			16.2	156	.00695
	Alpine fir.....																	
15	White fir.....	35	45	18.5	225	3,020	384	4774.775	80.4	(498.0	20.80	(1)	20.58	1,920	92.2	16.4	162	.00687
	Spiral, cut 3 to inch,																	
16	Spiral, cut 8 to inch; straight,	19	70	28.7	225	3,020	368	4794.840	76.0	(488.0	21.17	61	58.26	1,980	93.6	12.8	153	.00425
	cut 10 to inch.																	
17	Englemann spruce,	15	80	32.8	225	3,020	397	5024.900	81.0	(485.0	21.10	(1)	25.27	2,020	95.7	10.3	159	.00401
	Colorado.																	
	Amabilis fir.....																	

1 Split.

TABLE 58.—Quality tests of papers made from "commercial" pulps.

Stock No. of pulp.	Kind of wood.	Grinder run No.	Paper machine run No.	Ground wood in total	Weight per ream.	Thickness.	Mullen test.				Schopper tests.						Tintometer indications.							
							Total.	Points.	Per 0.001 in. thick-ness.	Points.	Per pound.	Horsepower per ton divided by strength factor.	Breaking length.			Stretch.		Breaking weight per sq. mm., sec.	Breaking length per ton.	Rod.	Green.	Blue.	Black.	
													Crosswise.	Lengthwise.	Average.	Crosswise.	Lengthwise.							Average.
1	White spruce.....	222	444	75	32 1/2	0.040	11.9	3.0	0.37	194	2,730	4,700	3,720	1.08	0.88	1.28	1,610	51.9	72	60	52	116		
2	Western hemlock.....	18	445	75	32	0.039	8.8	3.0	.52	256	1,880	3,740	2,810	1.26	0.82	1.04	1,760	39.2	65	59	58	118		
3	Sitka spruce.....	19	446	75	33	0.028	10.1	3.6	.31	406	2,430	4,200	3,360	2.80	1.46	1.14	2,080	34.6	64	52	48	139		
4	Lodgepole pine (Montana).....	26	447	80	33	0.040	12.6	3.2	.38	268	2,640	4,610	3,620	2.44	1.16	1.80	1,600	26.7	73	61	53	138		
5	Western yellow pine.....	27	448	80	33	0.038	9.8	2.9	.25	408	1,450	3,640	2,540	1.24	.98	1.11	1,720	24.9	65	60	60	115		
6	Balsam fir.....	22	449	80	36	0.048	8.9	3.2	.42	328	2,840	4,940	3,980	2.34	.76	1.91	1,820	28.2	71	57	46	126		
7	Lodgepole pine (California).....	26	450	80	34	0.050	9.6	2.4	.26	248	2,050	3,580	2,780	1.92	.92	1.42	1,150	43.1	64	54	54	132		
8	Red fir.....	19	451	75	34	0.034	13.2	3.1	.17	379	1,150	2,710	1,930	1.78	.74	.76	1,040	29.3	60	69	60	100		
9	Hemlock (one-half spruce).....	63	452	80	34	0.031	9.8	3.2	.39	232	2,640	4,650	3,640	2.16	.71	1.18	1,520	26.7	70	65	65	108		
10	Balsam fir (one-half spruce).....	23	453	75	33	0.040	18.2	3.5	.22	277	2,230	3,750	2,990	1.68	.94	1.31	1,320	38.6	75	62	55	124		
11	Tamarack.....	53	454	80	37	0.045	12.0	2.9	.22	352	2,650	4,150	3,400	2.00	1.08	1.06	1,320	27.1	62	57	57	124		
12	Noble fir.....	54	455	75	37	0.036	14.5	3.7	.29	292	2,850	3,550	2,700	1.82	.96	1.24	1,600	40.1	70	55	51	124		
13	Alpine fir.....	16	647	80	34	0.035	16.6	4.8	.43	296	2,940	5,100	4,020	1.52	1.00	1.41	1,870	31.9	58	54	53	135		
14	White fir.....	35	649	80	35	0.028	12.6	2.9	.27	470	1,790	3,830	2,810	1.12	.84	.98	1,800	22.1	50	50	50	145		
15	Engelmann spruce (Colorado).....	19	650	80	36	0.032	13.8	3.7	.28	290	2,770	4,820	3,850	1.90	1.00	1.45	1,720	20.2	83	77	66	74		
16	Amabilis fir.....	15	653	80	36	0.033	10.2	3.1	.25	230	2,880	3,460	2,640	1.12	.74	.93	1,690	27.6	83	57	57	123		
17											3,950	3,950	3,100	1.54	.98	1.26	1,490	32.5	76	63	56	105		
											2,960	3,500	2,500	1.78	.91	1.42	1,400	24.1	52	46	46	156		
											2,590	3,580	2,550	1.78	.90	1.06	1,650	40.2	61	66	61	96		
											3,370	3,560	2,710	1.14	.78	.96	1,800	30.7	54	54	54	133		
											2,800	4,630	4,800	1.96	1.04	1.28	1,800	52.2	72	63	60	103		
											2,830	3,120	3,440	1.70	.98	1.28	2,710	27.4	63	65	55	126		
											1,670	3,320	3,860	1.70	.88	1.02	1,920	27.8	77	70	67	87		
											2,790	3,910	3,800	1.82	.88	1.02	1,920	27.8	68	68	63	108		
											2,310	3,510	2,790	1.32	.78	1.05	1,920	24.5	75	65	58	126		
											2,440	4,490	2,810	1.38	.80	.99	1,370	26.5	62	57	51	89		
											2,150	2,630	3,310	1.23	.82	1.27	1,480	27.8	76	64	60	112		
											2,580	3,700	3,950	1.62	.88	2.06	1,385	24.3	68	63	59	99		
											2,770	3,700	2,780	2.74	.74	1.01	1,800	34.7	65	61	60	111		

APPENDIX B.

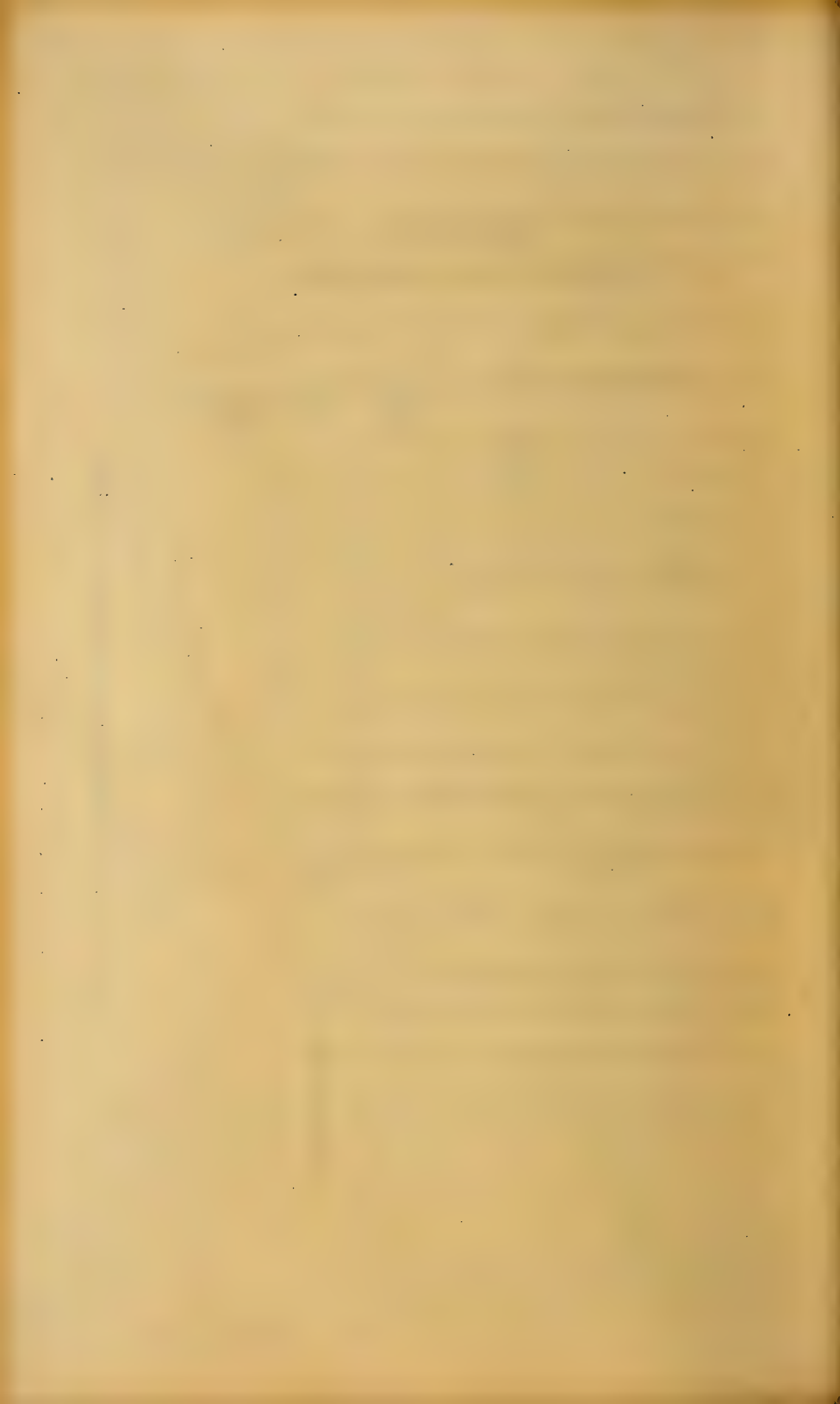
(Containing the following paper samples.)

Kind of wood used.	Untreated wood.			Cooked wood.
	Grinder run No. (Exp. paper).	Stock No. Unprinted news.	Stock No. Printed news.	Grinder run No.
White spruce.....	222	1	1	190
Western hemlock.....	18	2	2	9
Sitka spruce.....	19	3	3	6
Lodgepole pine (Montana).....	26	4	4	14
Western yellow pine.....	27	5	5	8
Balsam fir.....	22	6	6	27
	23	10	10	
Lodgepole pine (California).....	26	7	7	1
Red fir.....	19	8	8	2
Hemlock.....	63	9	9	161
Tamarack.....	53	11	11	27
	54	12	12	
Noble fir.....	16	13	13	11
Alpine fir.....	13	14	14	12
White fir.....	35	15	15	224
Engelmann spruce (Colorado).....	19	16	16	14
Amabilis fir.....	15	17	17	10
Jack pine.....	27			30
White pine.....	8			11
Aspen.....	2			3
Birch.....	9			5
Black gum.....	3			10
Loblolly pine (fall cut).....	6			19
Loblolly pine (spring cut).....	28			18
Lowland fir.....	13			2
Engelmann spruce (Montana).....	16			10
Western larch.....	8			1

¹ Or No. 62.

² Or No. 10.





White Spruce.

Grinder Run No. 222.

Western Hemlock.

Grinder Run No. 18.

Sitka Spruce.

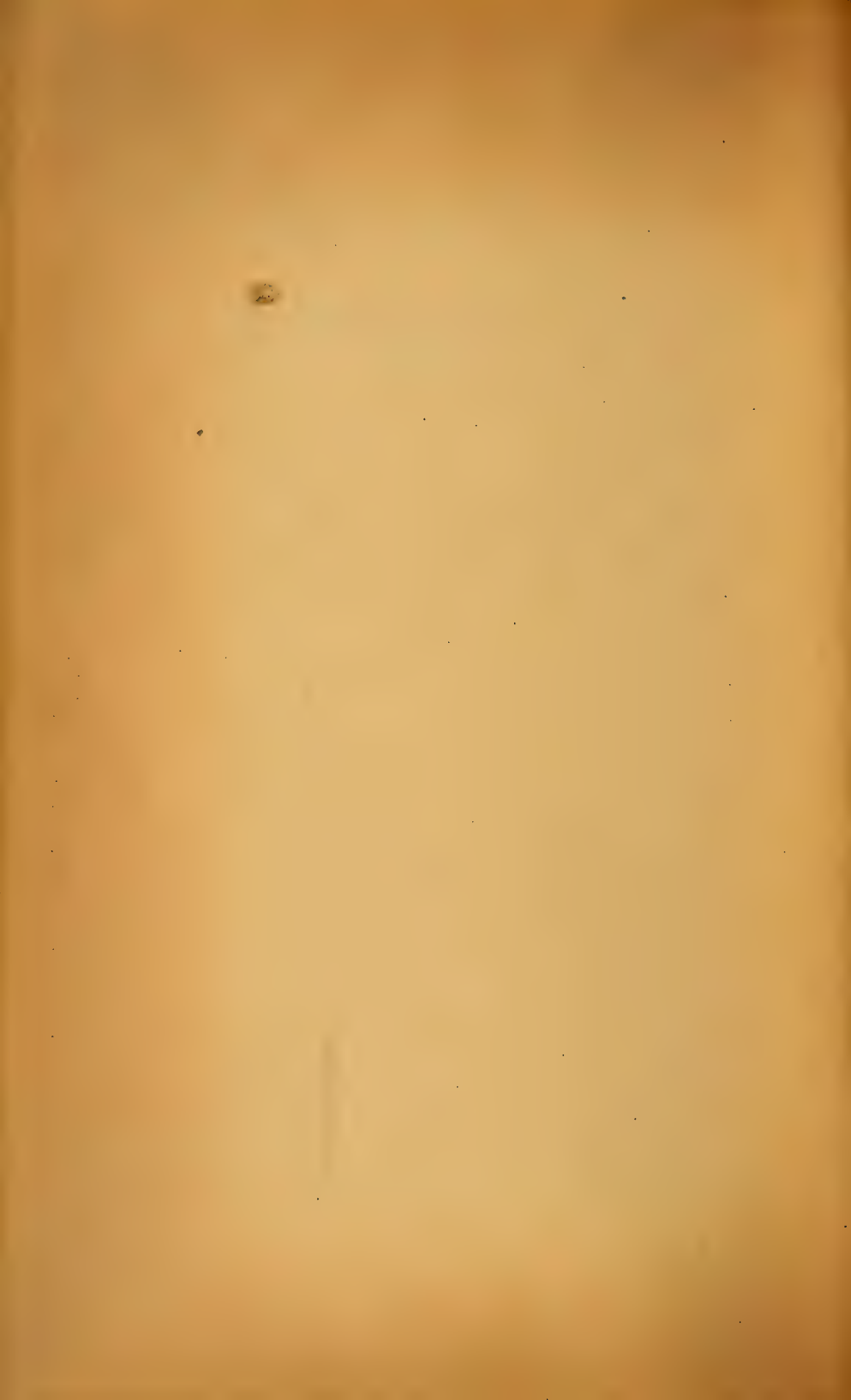
Grinder Run No. 19.

Lodgepole Pine. --- Montana..

Grinder Run No. 26.

Western Yellow Pine.

Grinder Run No. 27.



Balsam Fir.

Grinder Run No. 22.

Balsam Fir.

Grinder Run No. 23.

Lodgepole Pine. --- California.

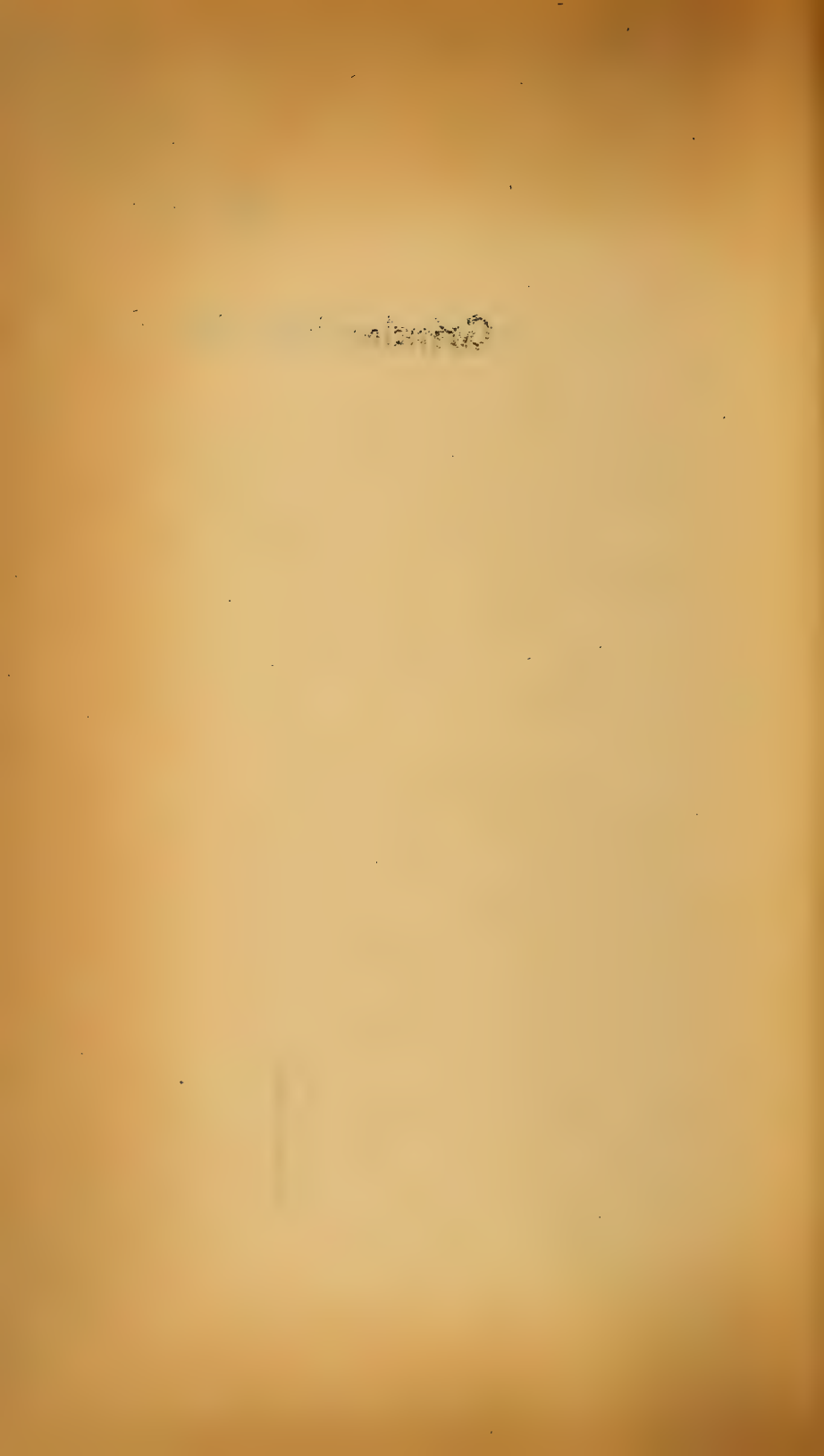
Grinder Run No. 26.

Red Fir.

Grinder Run No. 19.

Hemlock.

Grinder Run No. 63.



Tamarack.

Grinder Run No. 53.

Tamarack.

Grinder Run No. 54.

Noble Fir.

Grinder Run No. 16.

Alpine Fir.

Grinder Run No. 13.

White Fir.

Grinder Run No. 35

Engelmann Spruce --- Colorado.

Grinder Run No. 19.

THE UNIVERSITY OF CHICAGO

THE UNIVERSITY OF CHICAGO

Amabilis Fir.

Grinder Run No. 15.

Jack Pine.

Grinder Run No. 27.

White Pine.

Grinder Run No. 8.

Aspen.

Grinder Run No. 2.

Birch.

Grinder Run No. 9.

Black Gum.

Grinder Run No. 3.

Loblolly Pine --- fall cut.

Grinder Run No. 6.

Loblolly Pine --- Spring Cut.

Grinder Run No. 28.

Lowland Fir.

Grinder Run No. 13.

Engelmann Spruce --- Montana.

Grinder Run No. 16.

Western Larch.

Grinder Run No. 8.



Stock No. 1.

White Spruce.

EXAMINED FREE

22 Years' Experience, 17 Years in St. Louis. Assisted by a Staff of Skilled Eye Specialists.
leilly Optical Co.
 ATION, 615 LOCUST ST.

IAL PERMITS

all, 58, 35 Portland place; apo-
 Fields, 56, 4632 Cook; pneu-
 59, 615 Franklin; dementia.
 58, 77, 2205 Dickson; pneu-
 ert, 8, 2847 Osceola; tumor.
 erman, 53, 2120 Adams; heart
 1, 50, 2622 Indiana; carcinoma.
 nn, 51, 2115 Mitchell; hepa-
 n, 57, 3020 Prairie; nephritis.
 20, 4351 Easton; heart disease.
 38, 1915 Morgan; tuberculosis.
 69, 5009 Delmar; sclerosis.
 62, 800 Morgan; pneumonia.
 8, 8111 Garesche; apoplexy.
 1ermott, 58, 2712 N. Glasgow;
 8, 2822 Papin; nephritis.
 er, 38, 4463 Farlin; heart dis-
 n, 30, 3135 Brantner; tubercu-
 25, 4130A Green Lea place;
 n, 64, 4015 Page; apoplexy.
 1517 Picker; nephritis.
 1cours, 74, 1118 S. Ninth; ne-
 cherson, 31, 3013 Easton; phthi-
 58, 3932 Finney; heart disease.

CORPORATIONS

MISSOURI.
 N CITY, Mo., April 28.—Char-
 ged by Secretary of State Roach
 following new corporations:
 alty Company, Kansas City;
 \$8,500. Incorporators—John
 E. Heuben and H. J. Flucke,
 1vinger Investment Company,
 capital, \$21,000. Incorporators
 hworth, A. E. Berry and Lee
 Mining Company, Webb City;
 00. Incorporators—T. W. Hill,
 H. W. R. Shuck.

ILLINOIS.
 OLD, Ill., April 25.—Secretary
 ds to-day issued certificates of
 to the following:
 mpany, Chicago; capital, \$5,
 oporators—Arthur S. Banning,
 on, Aeon A. Aischuler.
 at Company, Chicago; capital,
 rporators—Geo. W. Costello,
 ennessy, Wm. R. Swissler.
 1son Metal Frame Action
 Chicago; capital, \$180,000. In-
 John K. Lenox Jr., C. J. Sulli-
 Sullivan.
 Manufacturing Company, Chi-
 \$25,000. Incorporators—Hen-
 A. P. McArthur, A. L. Blunt,
 ry Company, Chicago; capital,
 rporators—Albert H. Fry, Ota
 David Hurlburt.
 Drug Company, Chicago; capi-
 Incorporators—Max Shulman,
 lman, Mandle Salomon.
 1ture Company, Chicago; capi-
 Incorporators—Albert H. Fry,
 foot, David Hurlburt.
 & Co., Chicago; capital, \$2,500.
 —Samuel H. Fein, Barney
 am H. Patrick.
 rocer Company, Edwardsville;
 0. Incorporators—Frank Spind-
 1er, Wm. Fechrkolb.
 nstruction Company, Chicago;
 ased from \$100,000 to \$500,000.

OST AND FOUND.

Lost, bracelet, set with 10

ne, to St. Matthew's Church, thence to Calvary Cemetery. Friends are invited to attend.

WARD—Entered into rest on Monday, April 28, 1913, Bridget Ward (nee Kelly), mother of the late Michael and Lawrence Harty and Annie Dinnins (nee Ward) and dear sister of Mrs. Mary Laughlin of Richmond, Va., aged 76 years.

Funeral will take place Wednesday, April 30, at 8:30 a. m., from George Kriegshauser Undertaking and Livery Company's chapel, 4102 Manchester avenue, to St. Cronan's Church, thence to Calvary Cemetery. Friends invited to attend.

WHITMAN—Entered into rest on Sunday, April 27, 1913, at her home, 4556 Washington avenue, Annie E. Whitman, widow of Charles E. Whitman and sister of Mrs. Bradley D. Lee and Mrs. Carroll S. Gregory of Beloit, Wis.

Funeral from residence, Wednesday afternoon, April 30, at 2 p. m. Interment private.

OFFICERS and members of the Gertrude Charity Society are hereby notified to attend the funeral of Sister Lizzie Seligman, on Tuesday, April 29, at 10 a. m. from Isaac Rindskopf chapel, 435 North Euclid avenue. **MRS. F. SPIEGEL.**

WAGONER UNDERTAKING CO.
 3621 OLIVE. DAY AND NIGHT.
 No Charge for Wagoner Chapel.

MASONIC ORGANIZATIONS.

GEORGE WASHINGTON LODGE NO. 9. A. F. & A. M., will hold special communication Tuesday, April 29, at 6 p. m., sharp, for work in the Entered Apprentice degree. Visiting brethren welcome.
WM. S. CAMPBELL, W. M.
 Wm. L. Reynolds, Secretary.

MISSOURI LODGE NO. 1. A. F. & A. M., will hold a regular meeting on Thursday, May 1, 1913, at 7:30 p. m. Work in the degrees. All Master Masons are cordially and fraternally invited to attend.
J. S. McILVANEY, W. M.
 Anthony F. Ihner, Secretary.

TUSCAN LODGE NO. 360. A. F. & A. M., Special meeting at Tuscan Temple, 7:30 p. m. Tuesday, April 29, 1913. Work, E. A. and F. C. degrees. Visiting brethren welcome.
JAMES W. SKELLY, W. M.
 Alfred H. White, Secretary.

WEST GATE LODGE NO. 445. A. F. & A. M., will hold a special communication this Tuesday evening, April 29, 1913, at 7 o'clock for work in the Master Mason degree. Visitors fraternally invited.
FRANK LANDWEHR, W. M.
 Fred J. Kurtz, Secretary.

INDEPENDENT ORDER OF ODD FELLOWS.

BENTON LODGE NO. 275. I. O. O. F., meets every Tuesday evening at 8 o'clock, Wagner's Hall, Cherokee and Texas avenues. Visiting brothers welcome.
C. H. EULER, N. G.
 Emil Klug, Secretary.

ROYAL LEAGUE.

HAMILTON COUNCIL NO. 102. ROYAL LEAGUE, meets at Euclid Hall, Euclid and McPherson, every second and fourth Tuesday.
R. M. GILLILAND, Archon.
 A. B. Berne, Scribe.

ANCIENT ORDER OF HIBERNIANS.

DIVISION NO. 6. ANCIENT ORDER OF HIBERNIANS, meets every second and fourth Tuesday of each month in Hibernian Hall, Grand and Finney ays.
JOHN P. ENRIGHT, President.
 Jas. L. Kelly, Recording Secretary.

KNIGHTS OF PYTHIAS.

PACIFIC LODGE NO. 304. K. OF P. 354. Pine Street—On Tuesday evening, April 29, important business meeting. Members expected and visitors cordially invited.

NURSE GIRL—Colored. H. Alexander Hiegiand, 20 3514 Utah.

RAGTIME or vaudeville lessons; book sent free. **CL**

SODA DISPENSER—Ap- 5801 Easton.

SEAMSTRESS—Plain se if suitable, 14 N. 4th st.,

WASHERWOMAN—Good do washing on Monday, 3

WRAPPERS—Girls to w Kinney Bakery.

WOMEN to make apron work for good stitchers stamped envelope for p Specialty Co., 564 Wash Mass.

GIRLS WANTED—I ments. Peckham Ca 7th & Spr

HELP WANTED

Clerks.

A1 stenographer—private Leigh Bros., Frisco bldg.

BOOKKEEPER—Thoro bookkeeper, with executi Leigh Bros., Frisco bldg.

COLLECTOR—Young ma traveling collector; salary railroad fare. Apply betwe a. m. 501 Benoist bldg.

GROCERY CLERK—Cit references required. 954 G

The Trade

A PAPERHANGER; co work; best class of work; this morning, 2609½ Wash

BARBER—First-class barber, 501 N. 11th.

BARBER—Steady job, 16th st.

BARBER—Good barber, N. 11th.

BARBER—Good guaran Franklin.

BARBER for evening and 601 Hickory.

BARBER—Steady; \$12 a 1401 S. Broadway.

BARBER—Steady barber \$127 N. Grand.

BARBER—First-class yo week, 3208 Park.

BARBER—Steady man; and room, 3337 N. 11th st.

BARBER—Steady job; come ready to work, 1453

BARBER—Honest, sob wages, board and laundry.

BARBER—Good barber Saturday; good guarantee.

BARBER for Wednesd Saturday; \$5 guaranteed.

BARBER—Union barber day, 4485 Gravois. Call V

BARBERS, NOTICE—Just HENCKELS' and JACQUES SHEARS, \$1.40 and \$1.50 a BEGG, 502 N. 7th st., dealer razor and shear grinding solicite

BENCH MOLDERS—App leable Casting Co., 7800 N.

BOLTMAKERS—Apply Nut Co., Main and Florida

BLACKSMITH and hors Glvens, Ferguson, Mo. Bell

CARPENTERS—Apply A tional Stock Yards, Ill.

CARRIAGE PAINTERS and Clark av.

CLEANER and presser of tlemen's clothing. Call at Hotel, from 12 to 1.

FIRST-CLASS machinist Robinson Fire Apparatus 120th.

Stock No. 2.

Western Hemlock.

[illegible]

THREE PLUNGE M

SCAFFOLD, 1 D

Two Others, Working in
Get Fractured Ribs
Broken Leg.

VICTIMS CARRIED UP LA

Workmen Fall Thirty Fe
and Cries Bring Fore
to Their Aid.

One man was injured probabl
and two others seriously hurt
scatfold on which the three we
ing at the William Graver Taj
pany, Second and Ruffer stree
way yesterday afternoon. The
feet.
Joseph Ferris, who had been
but a short while, and whose
was unknown to his fellow lab
unconscious at the City Hospita
fractured skull and internal in
James Dixon, 33 years old,
Shenandoah avenue, had the
broken, and the left leg of jam
22, of 3830 Page boulevard, was
in two places. The two lat
taken to St. Mary's Infirmary.
The three men were at work
scatfold inside a big steel tank
they were building.
Enos Konoskia, the foreman
their cries, but could not read
until the other men, under th
tion, brought ladders and lower
inside the tank. They were ther
up a line of men formed on ea

ED: Can you take a hint? You can ge
at Lottia for \$1 a week. 2d floor, 308 N.

39 DIVORCES ARE GRA

Seven New Suits for Martin
Are Filed.
Divorces granted yesterday
Dudley F. from Mary M. Williams,
B. from Frank J. Swatek, John
Annie Mallon, Emma from Will
Patching, Mary N. from Thomas O
Eva A. L. from Robert Bishop,
beth from Peter McNally, Le
from Orlando Gardner, Maud
Thomas Smith, Lulu from Ber
Buesing, Carrie from Levi Keyes
from W. E. Long, Alma from

THE BUD



W.L. DOUGLAS
\$3.50, \$4.00 & \$4.50
SHOES
THE LARGEST MAKER OF MEN'S
\$3.50 & \$4.50 SHOES IN THE WORLD
Look in W. L. Douglas store
windows and you will see shoes
\$3.50, \$4.00 and \$4.50 that are
er makes costing \$5.00 to \$7.00.
only difference is the price. Shoes
leathers, styles and shapes to suit
body. If you could visit W. L. Douglas
factories at Brockton, Mass., and see for
how carefully W. L. Douglas shoes
made, you would then understand why
are warranted to fit better, look
er, hold their shape and wear
ger than any other make for the price
e Best \$2.00 and \$2.50 Boys' shoes in the World.
See that W. L. Douglas name
is stamped on the bottom.

TAKE NO SUBSTITUTE.
W. L. Douglas shoes are not for sale in your vicinity
order direct from the factory and save the middleman's
profit. Shoes for every member of the family,
at all prices, by Parcel Post.
Write for Illustrated Catalog. It
will show you how to order by mail and why
you can save money on your footwear.
W. L. DOUGLAS, Brockton, Mass.

W.L. DOUGLAS SHOE CO.: 616 Olive St., St. Louis

INDIA
TEA
ngth and Richness

Stock No. 3.

Sitka Spruce.

Here
Thursday:
st To-Night



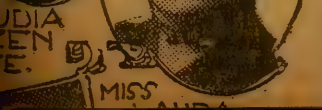
MRS. D. A. McDUGAL



MARGARET ROE



MRS. ARTHUR H. GEISSLER



MISS ANNA

\$500 SERUM FEE SET BY FRIEDMANN

Must Be Paid Down if Patient
Has It—Poor to Be Treat-
ed Free.

Sitka Spruce

HE GOES TO CANADA TO-DAY

Dr. Maurice Sturm in Charge in
New York—Contract With
Eisner Signed.

NEW YORK, April 28.—Dr. Friedrich Franz Friedmann will depart to-morrow for Montreal, where he is to inspect patients he treated in that city about six weeks ago.

He will return here within a few weeks to begin the instruction of physicians in the use of the turtle cultures at the Friedmann institute, which will be established in accordance with the contract Dr. Friedmann entered into with Moritz Eisner.

The first authentic announcement that the contract was made was issued when I. N. Lehmann of the law firm of Lev-entritt, Cook & Nathan gave out a statement saying that "an arrangement" had been definitely arrived at between the specialist and Mr. Eisner providing "for the preparation and use of the Friedmann vaccine in the United States."

It was denied that the idea of having the vaccine prepared in each State at the institutes to be established in each was intended in any way as a method by which interstate traffic in the cultures and interstate regulations of the Government might be evaded.

Dr. Maurice Sturm, who will represent Dr. Friedmann, made this statement to-day:

"The first Friedmann institute" will be established in New York City after my return from Canada. The upper floors will be fitted out as laboratories and operating rooms. There will be beds in the institution. No physician in this State except my assistant and myself will have any of the serum.

"I will be the head of the institute here, and under no circumstances will we give any of the Friedmann cure to any physician. The charges will be

Weather—Fair



Stock No. 3. A New
My-Letter Pa

Nightshirts are garments that young men of taste have desire

With your own handsomely embroidered handkerchief pocket "Faultless" sleepwear have the intimate touch that adds a charm to the most restful nightwear owned.

These garments celebrated Faultless made in a variety of sizes. They come in large raised initial brodered on the p

All Sizes in A

Here are two of these new garments our Men's Nightwear

"Faultless" My silklike in appearance longer than silk. Cool neck, and trimmed of silk frogs. Wh Unusual value at \$

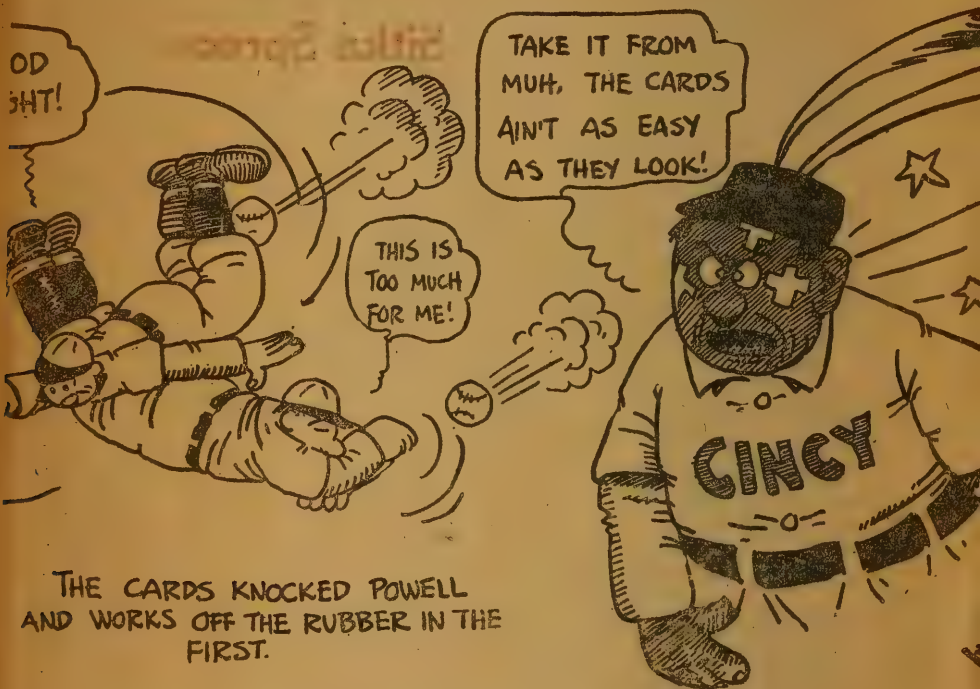


The S

A Sale o

SEBALL AND O

THE EXPENSE OF TINKER'S REDS—HARRY SALLEE PICK



THE CARDS KNOCKED POWELL AND WORKS OFF THE RUBBER IN THE FIRST.

LL FACTS

S GAMES.

I League.
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at Brooklyn.
Philadelphia at Boston.
in League.

York.
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Association.
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Indianapolis.
at Toledo.
St. Paul at Columbus.

I League.
at Davenport.
Decatur.
Quincy at Springfield.

NDINGS.

Cardinals Win Three Out Sallee Stands Tinker's Men on T Locals Bombard Three Ci

BY DICK COLLINS.

Three out of four from the Cincinnati Reds is going some for a team that lost three out of four to Pittsburgh and two out of three to Chicago. "Hug's" men believe in making hay while the sun shines.

There was a noticeable improvement in the Cards' work as soon as the Reds struck town. Some people are unkind enough to attribute it to the weakness of the Reds. But they over-

looking for right off the reel Oakes punched a single to centering Mowrey and Sheckard. tossed the ball home and Oakes second. Gee, how those Red o love to zing the ball around! walked. Joe Tinker danced land fling in the middle of mond.

"You're wilder than Powell, "Tink" to his pitcher.

"Don't bawl me out, that's s I can't stand," replied Works.

"Well, if I can't bawl you

Stock No. 4.

Lodgepole Pine. --- Montana.

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AGS ILL

DECATUR, Ill., April 28.—Wayne Ulrich, 8-year-old son of Walter Ulrich, a barber, was responsible for the discovery of \$3,000 in gold in two small cans contained in a larger can in the coal shed last week.

The small boy's curiosity alone pre-vented his mother throwing the can in- to the garbage heap, and Ulrich when they moved recently would have sab- doned the old trunk containing the cans without looking into it.

His wife advised him to keep it be- cause of sentiment, the trunk belonging to his father, who died in 1907. "Wes- ter- open it, and \$5 and \$10 gold pieces were found, neatly wrapped in paper.

PLOT AGAINST KAISER BARED

Berlin Police Warned of Proposed At- tempt on Emperor's Life.

BERLIN, April 28.—A warning that an attempt was to be made on the life of Emperor William during his visit to Karlsruhe, Baden, was received yester- day by the police authorities in Ber- lin, anonymously, from abroad.

They immediately informed the police of Karlsruhe and Frankfurt, and strin- gent precautions were taken to pre- vent any outrage.

PIERCE MAKES A DENIAL

Testimony in Hearing Did Not Reflect on Eben Richards.

The editor of the Republic, Eben Richards, in issue of April 26, that "Pierce testified son-in-law signed his name without his knowledge," and sent as guarantee for loans aggregat- ing \$2,100,000," is absolutely untrue and is cruelly hurtful to Mr. Richards and myself. There is no foundation for your statement in the official notes of my testimony before Commissioner Muench, wherein I stated as follows:

When Mr. Thompson was loaning his accounts to Mr. Van Barcom and I was loaning my securities to Mr. Van Bar- com, and in my absence and at the request of all the officers of the Na- tional Bank of Commerce, my son-in- law, Mr. Richards, joined in my name with Mr. Van Barcom in guaranteeing the National Bank of Commerce the pur- chase of \$1,450,000 Tennessee Central Railroad bonds.

Stock No. 4.

During the past many years Mr. Rich- ards has held my full power of attor- ney, and now holds it. Please conspicuously publish this let- ter in full in your to-morrow's issue.

H. C. PIERCE.
St. Louis, April 23.

Free Bridge Committee to Consider Building of Approaches Before Then.

There is little chance that the special free bridge bond election will be held before September. The Election Com- missioners have informed Mayor Kiel that the election could not be held un- til July at least.

The Mayor is opposed to holding the election in midsummer, as many voters will be away on vacations, so the elec- tion probably will be postponed until after vacation time.

The joint Free Bridge Committee of the Municipal Assembly will convene again Thursday afternoon to discuss the advisability of selecting an ap- proach to the bridge before the elec- tion.

BOND ELECTION IN FALL

Roommate Found Dead in Bed.

Oscar P. Hoffman, 36 years old, a hattermaker, was found dead in bed Sun- day by his roommate, George H. Far- rison, at 3119 Olive street. The physi- cian summoned said death was due to carbolic acid poisoning. An inquest will be held this morning.

Roommate Found Dead in Bed.

Roommate Found Dead in Bed.

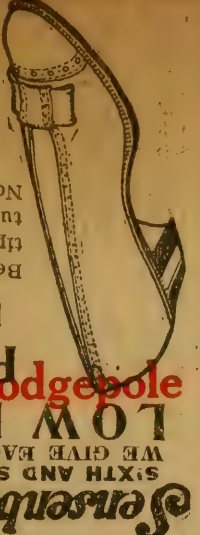
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Jensenbrenner's LOW HEEL PUMPS FOR WOMEN

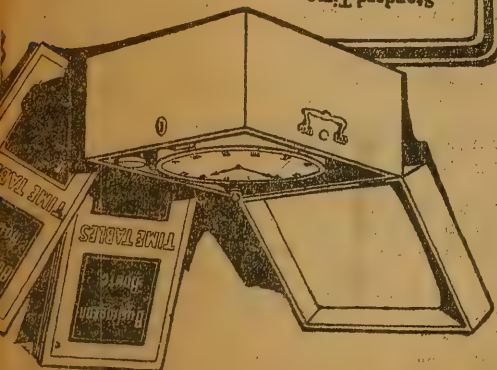
WE GIVE EAGLE STAMPS SIXTH AND ST. CHARLES

Best gummetal calf, tip or plain toe, turn or welt soles. Nothing like it in town for less than \$3.50.

\$7.50



True Timekeeper



The Jeweler's Chronometer and Burlington Time Tables are standard set by chronometer. Appointments on the Burlington Route are made by ton time tables and kept by means of Bu

"On Time" Service.

Hundreds of trains daily maintain Burlington's "On Time" record.

To Kansas C

"On Time" Go via the Bu

—and there are many other features.
—Observation-Club Car; you can eat, sm
—Spacious Smoking Room; private enoug
—Midnight Train—the famous "Night H
—No stop to Kansas City; no confusion,
sleep on the "Night Hawk."
—Complete dining car service; meals at ar
—Appetizing breakfast—just the kind you
"On Time" Every Day is the Burlington

"Night Hawk" leaves St. Louis ev

Two other perth
the "Early Bird" le
p. m.—the "Day I
9:06 a. m.

Just call up—we w
J. G. DELAPLA
Phones: Main or Cent



"The Electric-Lighted, Block Protect

the execution of the instructions. Notwithstanding the advantage that these Gov might be gained by an immediate rec- ized a c omission. It is believed here that the obtain

when the matter will be heard on its merits.
The Court denied the writ of prohibition sought by Jean Lassagne of Grinn of the St. Louis Circuit Court from entertaining any further an appeal from a decision of the Probate Court of St. Louis in the final distribution of the estate of Peter Pelz, deceased.
Lassagne was one of the heirs to the estate and objected to this. The estate is inventoried at \$23,719, and Lassagne's share under the distribution and will is \$1,310.
Following is a partial list of the motions disposed of and the other proceedings in the court in banc to-day:
Gold Issue Mining and Mineral Company, res. vs. Pennsylvania Fire Insurance Company of Philadelphia, app.; respondent's motion to transfer to St. Louis Court of Appeals; appellant's suggestion in opposition to motion to transfer; motion overruled.
William P. Houston, resp. vs. Pulitzer Publishing Company, app.; appellant's motion to tax cost of printing abstract of record allowed for \$81.
Edward D. Jackson, pl., resp. vs. Edward Butler et al., del., app.; defendant appellant's motion to tax cost of printing abstract of record allowed for \$81.
P. O'Hara for leave to file brief; leave granted.
State ex rel. Tebbels vs. Holtkamp, J. Richards et al.; argued and submitted to the Court in the matter of Letitia Todd Brock vs. Joseph A. Wright, resp.; respondent's motion to strike out certain statements from State ex rel. Circuit Attorney, rel., vs. Joseph A. Wright, resp.; respondent's motion to amend and amend sustained.
Judge; relator's motion to amend and amend sustained.
State ex rel. Tebbels, rel. vs. Holtkamp, J. Richards et al.; argued and submitted to the Court in the matter of Letitia Todd Brock vs. Joseph A. Wright, resp.; respondent's motion to strike out certain statements from State ex rel. Circuit Attorney, rel., vs. Joseph A. Wright, resp.; respondent's motion to amend and amend sustained.
Respondent filed in 1938.
Neither, with petitioner's reply to return of

MARRIAGE OF GIRL, 17, VOID

Poster Mother Refuses to Let Young Wife Live with Husband.

The marriage of Cora Berger, 17 years old, and Otto Berger, whom she was persuaded to marry when she was 15 years old, was annulled by Circuit Judge McGuffin yesterday.
A woman in whose bakery the girl was employed induced her to marry Berger, a baker at the place, she stated. The marriage took place at St. Charles. The woman for whom the girl worked accompanied her and Berger.
They returned to St. Louis immediately after the marriage and called at the home of the girl's foster mother, Mrs. Henry Duwel, of 3227 Hickory street. Mrs. Duwel would not let the girl live with Berger.

Robbed, Thrown from Kads Bridge.

Adam T. Dettling, who says he is an engineer of Bonne Terre, Mo., was found by Patrolman Brosnahan of the Car Street Station on the levee last night, with his clothes dripping wet. He said three footpads robbed him of \$4.50 and threw him off Leads Bridge into the Mississippi. He was held at the City Dispensary. Dettling was well clothed and wore a gold watch and a heavy gold ring.

Stock No. 5.

Western Yellow Pine.

Quick service.

ATHER REPORT

Forecast by States.
INGTON, D. C., April 28.—Forecast:
—Fair and warmer Tuesday.
y, probably fair.
y, fair and warmer Tuesday.
y, probably fair; moderate, varia-
a—Generally fair Tuesday and
y.
as—Fair Tuesday and Wednes-
ate south winds.
ae—Fair Tuesday and Wednes-
and Nebraska.—Fair Tuesday and
Wednesday; not quite so warm
y.
—Fair Tuesday and Wednesday;
air and warmer Tuesday. Wednes-
—Fair Tuesday and Wednesday;
emperature: moderate, variable
y—Fair Tuesday and Wednesday;
perature.
ions taken at 8 p. m., seventy-
dian time.

Dr.	Tp.	Mx.	Prec.	Weather.
S.....N	62	64	....	Clear
Tex.....S	78	82	....	Clear
ity,N.J.S.E	52	58	.22	Cloudy
Ga.....W	54	62	.20	Clear
m, Ala..N	56	58	.06	Cloudy
ho.....W	50	52	....	Cloudy
ass.....N	50	50	.42	Cloudy
Y.....NE	54	60	.28	Rain
.....N	60	64	....	Clear
hberta..NE	36	40	....	Cloudy
S. C. W	58	60	....	Clear
ga.....NW	50	54	....	Cloudy
Wy.....S	66	72	....	Pt cloudy
Ill.....N	46	48	....	Clear
O.....NW	46	46	.26	Rain
O.....N	44	46	.70	Cloudy
Kas.....SE	68	72	....	Clear
stili.....SE	70	74	....	Clear
la.....NE	62	66	....	Clear
.....N	44	44	.84	Cloudy
olo.....NW	74	80	....	Pt cloudy
.....la..SE	64	68	....	Clear
ich.....N	48	48	.12	Clear
te, N. D. S	70	74	....	Clear
r, Kas..SE	72	78	....	Clear
la.....NE	62	64	....	Clear
inn.....NE	42	48	....	Clear
olo.....S	68	70	....	Pt cloudy
Alb't.NW	32	34	.02	Cloudy
Tex.....SW	82	84	....	Clear
al.....SW	48	52	.10	Clear
Ind.....NE	52	54	....	Cloudy
Allz.....SW	58	64	....	Clear
h, Ark...E	68	70	....	Clear
h, Tex..SW	84	88	....	Clear
l.....NW	70	70	....	Clear
Tex.....SW	68	74	....	Clear
ont.....NW	42	62	.02	Cloudy
D.....S	68	72	....	Clear
ls, Ind. N	52	52	.12	Pt cloudy
le, Fla.NW	64	70	.04	Clear
ty, Mo...E	62	68	....	Clear
as.....N	62	68	....	Clear
k, Ark..SE	64	68	....	Clear
as, Cal.SW	60	68	....	Clear
ky.....W	46	46	.08	Cloudy
Tenn..NW	64	64	....	Clear
.....SW	72	80	....	Clear
la.....NW	66	70	....	Clear
y, Ala..N	60	64	.01	Cloudy
Tenn..NW	50	52	....	Cloudy
ns, La. N	70	74	....	Clear
.....SE	54	64	1.08	Clear
.....W	50	56	....	Clear
.....S	54	66	.01	Rain
.....S	56	58	....	Clear
Ok.....S	78	84	....	Clear
eb.....SE	64	68	....	Clear
la, Pa. E	58	62	1.72	Cloudy
ariz.....W	86	90	....	Clear
Pa.....NW	46	46	.32	Rain
Ore.....SW	52	54	.04	Cloudy
lo.....SW	78	82	....	Clear
.....NW	54	56	.12	Clear
S. D. S	80	82	....	Cloudy
Cal.....S	62	64	....	Cloudy
.....S	62	58	....	Clear
Mo.....E	64	68	....	Clear
Minn..SE	64	68	....	Clear
City.....S	72	74	....	Clear
lo, Tex..S	80	84	....	Clear
Cal.....W	62	66	....	Clear
isco, Cal. W	54	58	....	Clear

Is water free of minerals. Water that absorbs the mi-
erals of your system and sluices out t
dregs of the body.

It's not food that counts—it's wat-
Spend a few dimes for CRYSTAL WATER
and be happy and healthy.

A Cooler Free.

Five Gallons CRYSTAL WATER 37¢
in your office. 50¢ in your home. The d-
ferent only cost of delivery.

Stock No. 5.

St. Louis Crystal Water and Soda C

Main 600. Central 35

Western Yellow Pine.

FIRE INSURA

The Jefferson Mutual Insurance Co., of St.

OFFICE, No. 317 CHESTNUT ST.
Phone—Bell, Main 1665.

MERCHANTS' EX
Kinloch, Ce

This company begs to inform its members and the general pub-
in position to write Fire Insurance after April 30, 1913, as her-
servative policy of underwriting will be carried out as in previ-
If you have desirous business to offer, call or phone and v
service.

The following well-known business men compose its officers:

DIRECTORS.

Wm. G. Mueller	Wm. Koenemann	Gustav I.
Otto J. Wilhelm	Otto F. Stifel	Henry H.
Christoph Hilke	F. W. Hoffmeister	Ernst H.
Aug. F. Klasing	Henry Griesedieck Jr.	Julius L.
Aug. F. Klasing,	Julius L. Winkelmeier,	L. W. Se
President	Vice-President	Oscar J.

AGENTS.

C. Kraleman & Son	Otto A. Hampe	H. von I.
Miss Alice Weixman	Adolph T. Prag	Henry Se
Chas. T. Bessehl	Matthias Backer Jr.	Schiele d

All trains will be Resumed

St. Louis to the I

via

BALTIMORE & O

Southwestern R. R.

Effective at Midnight Sunday, Ap

With the exception of "Queen City Limited," leaving St. L
which has been annulled for the present.

F. D. Gild

KIEL MEETS B. P. I. ON BOAT

Mayor Makes Trip to Chesley Island
on Erastus Wells.

The harborboat Erastus Wells, the
vessel on which former Mayor Kreis-
mann and his "cabinet" of advisers
met and discussed city affairs almost
weekly last summer, was the scene yes-
terday of a similar conference between

PROTESTANTS

Joint Commission
Adopts Me

COLUMBUS, O., A
commission of the
and the United Bre
session here to-
adopted a basis of

four boys. Miss Mat-valdictorian and Miss salutatorian. The fol-lies: Misses Mattie Con-letha E. Hard, Nellie ge Wilton, William G. and Russell Carter.

S COUNTY.

ness Men Banquet.

ness Men's Association. banquet last night at ewood. Addresses were Attorney Lashly and Murdeman.

TES IN SESSION

Refers Free Bridge Organizations.

representing fifteen s attended the reg-isting of the Central the Public Library

h spoke in favor of ound for more parks ost assessed against was benefited by

uperintendent of the y-House, told of the l by that institution tablishing of a larger part of the city.

approved the bill for of the street car serv-ice repeal of the Pub-mission. The Free referred to the vari-ung for the ventila-s, for the wrapping the disposal of ashes, e approved.

O RACERS HELD

ness Arrest of Two in Slave Case.

Cal., April 28.—Delv-e white slave bands ne police to-day ar-ry Casse and Richard tomobile racing driv-preferred by Evelyn ld schoolgirl. rrested in the apart-ner society woman, s now suing for di-vorced tried to evade ding himself in his ulice tore down the

d to Succeed Dunn.

apt. William J. Mac-ice of Supervising. In-poats in the St. Louis ed Joseph J. Dunn, weeks ago, was sent st week. Capt. Mac-nited States Inspector lers in this district The promotion will n the office of Inspec-This will be filled by e the civil-service list rm another district.

Two Hundred Strike at Baker Foundry. When the whistle at the Baker Foundry, Belleville, blew yesterday morning 200 men walked out of the shop on a strike because the company has failed to employ union men in the polishing room.

MARQUETTE RECEIVER ASKED

Court Is Petitioned to Remove Officers of Downtown Hotel.

Arthur Thacher applied to the Circuit Court yesterday for a receiver for the Glancy & Watson Hotel Company, which conducts the Marquette Hotel, at Eighteenth street and Washington avenue.

The company is capitalized for \$100,000. Thacher owns ten shares of the stock and T. H. Glancy, president and manager, owns 750 of the 1,000 shares.

The company was organized in February, 1907, with Glancy and M. D. Watson managers at salaries of \$3,600 a year, it is stated. Glancy bought Watson's interest in August, 1910, and has been drawing \$600 a month salary, it is asserted.

The court is asked to remove Glancy and the Board of Directors and require an accounting.

Engineers Discuss St. Louis Chapter.

Charles F. Rand and Bradley Stoughton, president and secretary, respectively, of the American Institute of Mining Engineers, were entertained at a dinner at the St. Louis Club last night by Missouri and Illinois members of the association. The advisability of organizing a local chapter of the institute as a "get-together proposition" for Missouri and Illinois engineers was discussed. Both Mr. Rand and Mr. Stoughton addressed the diners, while other speakers were former Gov. D. R. Francis, H. A. Buehler, State Geologist, of Rolla, Mo., and Capt. R. W. Hunt of Chicago.

Poultry.

NEW YORK, April 28.—Live Poultry—Today is the Hebrew Last Passover, and with the buyers absent, there was no business and no poultry was unloaded. Some 9 cars arrived on trk., but will not be unloaded till to-morrow.

Dressed Poultry—Receipts 1,488 pkgs. Very little fresh-killed poultry here of any description, but large fowls of fowls went at 18½@19c, but large fowls are difficult to strain up to 18½c. Old roosters scarce and firm. Squabs a trifle easier and only fancy exceeding \$4 on an 8-lb. average. There were a few lots of frozen fowls thrown on the market and held up to 19c, but buyers are reluctant to pay that price, and very little business reported. Frozen roasters held with more confidence. Frozen turkeys active.

Fresh-Killed Poultry—Dry-packed turkeys, hens, av. 22@23c; toms, young, av. 22c; do. old 21c.

Fowls—Box-packed, 12 birds to box: Western dry-picked, 60 lbs. 19c; do., 48@55 lbs., 19c; do., 30@42 lbs., 17½@18½c; do., under 36 lbs., 16@16½c; do., bbls., over 5 lbs., 18½c; do., 4 lbs. each, 18½@19c; Western dry-picked, iced, 18½@19c; do., bbls., 3@3½ lbs. each, 17@18c; do., bbls., Southern and Southwestern, 17½@18½c; scalded, bbls., other Western, av. 17½@18½c.

Old Roosters—Dry-picked 14½c; do. scalded 14½c.

Squabs—White, fancy, 10 lbs. to doz., \$5@5.50; do., 9 lbs. to doz., \$4.50@4.75; do., 8 lbs. to doz., \$4.45; do., 7 lbs. to doz., \$3.25@3.50; do., small, 6@6½ lbs. to doz., \$2.25@2.50; culs, per doz., 65@75c.

Guinea Fowls—Old, per pair, 85@90c; do. young, per pair, \$1@1.15.

under 21c; slips 18c. Guinea round, per doz., \$2.50.

DRESSED ICED POULTRY.—and demand both light. Quote: C keys 16c; small and poor 12c; 2 cocks 10c; chickens 19c; broilers 6c to 10c; ducks 13c; capons 24c 17c.

PIGEONS AND SQUABS.—C pigeons at 75c per doz. Squabs—Fers (7@8 lbs. to the doz.) \$3.50. Large homers (9@10 lbs. to doz.) some small sold at \$3; common 1 and dead pigeons 60c per doz.

VEALS—Market firmer, there a few offered, but receipts did not arrive until about noon. Good meat for choice medium weights. Choice, 180, 9c per lb.; do. 150 to 175 lbs., 180 to 200 lbs. at 8c; rough, coarse tics of over 200 lbs., as well as under-weight, at 6@7c. Sheep at bucks at 3@4; yearling lambs for 6½@7½c for choice; 4 for lambs—Choice fat, weighing 45@50 at \$4.50 per head; small and Sheared sheep sell at 1c and 1½c than full-wooled.

ROASTING EGGS—Quote, each: at \$2@2.25; 25@30 lb. \$2.75.

FRESH FISH—Quote, per lb. dressed, 3½@4½c; do. round 2½c dressed, large, 6c; do., dressed, 4½c; do. round 3c; sunfish 2½c large, 11c; do. medium 8c; do. black bass, 2½ lbs. and over, 9c @2½ lbs., 10c; do. order size, 8@12c; spoonbills, 4@10 lbs., 8c; do. and 11c; do. less than 1 lb., for eggs, collar bones off, 10c; do. lar bones on, 9c; bullheads, dressed, collar bone on, 6c; white perch, dressed, round 2½c; grass pike 5c; eels, shell turtle, dressed, 7c; do. round meat 8½c; frogs, large, per doz., medium 75c; do. small 50c.

Hides, Furs, Wool, Etc.

FEATHERS—Prime white live and prime gray do. 44c; old white 30@27@31c; xx 16@18c; xxx 10@10c; 2 bare 10c; 10c; small 15c; all large. Duck—White 44c; dark 30c.—Prime dry-picked body 3c; wet, 3c; quill-mixed 2c. Turkey—Body, 1c; quill-mixed 18c.

BEEFWAX—Quote prime at 31c; impure and inferior less. LARD—Quote full weight \$1 each for green or dry; small 4c; spring lambs at 10c to 20c—latter, kill. Dry 10c per lb. for light to sandy and heavy.

GOAT SKINS—Quote at 25@40c and 5@15c.

WOOL—A few small lots of the arriving and selling on basis of given herewith; market unsettled, and accurate prices not as yet set. The trade awaiting a settlement of the question; besides shearing is being. Quote, nominal prices: Near-by 17c for low to 19c for choice 12c for heavy to 16c for light 15@17c; burry 11@13c for heavy for slight; Southern 10c for burry to 17c for clear; fall clip 9c to 16c, and fine 11c for sandy; Texan medium 16@17c; do. heavy 14@15c; ern or Western 17c for dark to bright medium; 10c to 13c for fine for hard burry to 18c for slight; 25c for clear to 28c for clear; and 10c for burry to 25c for short clear for long lustrous.

TO GROWERS OF WOOL.—To successfully with foreign growth, to realize top market prices, it is necessary to put the wool in proper marketable condition. The wool must be washed in the wash tub and when sheared in fleeces with a light, hard glass. After all dung, skirts and other foreign matter practicable is removed, should be separated from burry, damp, chaffy, fine, etc., and otherwise made as good as possible for manufacturers.

FURS—The season is virtually over as offerings are more or less scarce. Prices are about two-thirds of winter prices. Current receipts quotable round coon 25c to \$1 milk \$1 to \$2, opine to 50c skunk (Central) \$1 to \$1.50, rat 10c to 15c, gray fox \$1@1.50, red fox 4c; wolf 25c.

HIDES—Market inactive and waiters buying only for immediate use. Green salted in light receipt and good many "shedders" which are in the dry quiet.

Wet Salted.	Dry Salted.
Round 13½	Flint, round 13½
No. 1 13½	Salted 13½
No. 2 12½	Flint, bull 12½
Bull 10½	Culls 10½
Glue stock 8½	

Uncured or fresh 1½c per lb. for

Stock No. 6.

Balsam Fir.

R SPORTS

J. B. SHEPHERD
WILBUR
ROY STOCK

By George McManus



From Reds After First Twirlers

ms instead of playing in-
l. At this stage of the
l was taken out and Works
Powell wore a smile as he
x and Works advanced to
with the solemnity of a
Works got what he was
right off the reel. "Reb"
hed a single to center, scor-
y and Sheekard. Marsans
all home and Oakes grabbed
e, how those Red outfielders
g the ball around! O'Leary

CLASSY FIELDING WINS FOR TIGERS

Angerer Allows Four Hits and
Pollom, in Box for Kansas
Aggies, Gives Five.

COLUMBIA, Mo., April 28.—Brilliant
fielding gave the Missouri Tigers a 2-1
baseball game against the Kansas Ag-
gies this afternoon.

Both sides got men on bases frequent-
ly, but snappy playing cut off most of
the chances of scores.

TRENDALL F. TO WHIP N

Light Weights Clas
at Future City
To-Nig

While Harry Trendall was
favorite over Pierce Ma-
ture bout of the box
Future City A. C. to-
the latter point to t
has never been beate
may spring a surpris
Trendall is one of

LEADER'S NSE EXTENDED

ntinue Mrs. Pankhurst's
While Suffragettes
ade House for Siege.

PEERED BY CROWD

tocked With Provisions
paration for Battle
ith Authorities.

April 28.—The expiration of
icensed under which Mrs.
Pankhurst, the militant suffer-
er, was released April 12,
ay Jail, where she was
ee years' imprisonment,
ut crowd to assemble to-
ue where she has been
eover from the effects of
strike."

s expectation of seeing her
rned to jail was disap-
r authorities having in the
ided to extend her license
unsatisfactory health.

time, the occupants of the
Mrs. Pankhurst was stay-
ed it in a state of siege.
locked with a two months'
visions.

rs of her family and some
merents were quartered
o upper floors, leaving
e furniture on the two
and this was plainly vis-
the uncurtained windows.
et door was barricaded,
of the password being ad-

Pankhurst's feminine
ed off from the house
ia Pankhurst, during the
shooting crowd tried to

square which the house
red by a strong force of
y householders and their
ollowed to pass the line.
orts of militants arrived
sly meeting, only a few
necrating the cordon and
house.

illicants who had been in-
said afterwards that it
een necessary for the po-
ee barricades before they

MEMORIAL ENVOYS ON WAY WESTWARD

Congressional Delegation to Jef-
ferson Ceremonies in St. Louis
Quit National Capital.

HIGGINS ALSO IN THE PARTY

Page and Swanson, Who Expect-
ed to Come, Have to Aban-
don Trip.

WASHINGTON, D. C., April 28.—Four
Senators, eight Representatives and
Sergeant-at-Arms Higgins of the Sen-
ate and Gordon of the House departed
this evening to represent Congress at
the dedication of the Jefferson Memo-
rial in St. Louis Wednesday.

Senators Page of Vermont and Swan-
son of Virginia, who had expected to
attend, found it impossible to go.

Wesley L. Jones of Washington, Wil-
liam Hughes and James E. Martine of
New Jersey and William S. Kenyon of
Iowa are the senatorial members of the
party.

Mr. Jones is one of the few far-West
Republicans who remained a supporter
of Taft for the Republican nomination
last year.

He was the only Senator who, having
voted for the expulsion of William Lor-
imer when the Illinoisan's claim to sit
in the Senate was first tested, changed
his vote when the second test came.

When elected Senator Kenyon was an
Assistant Attorney General under the
Taft administration.

The House committee are: W. A. Cul-
lop of Indiana, W. P. Borland of Mis-
souri, J. Charles Linthicum of Mary-
land, George White of Ohio, Julius
Kahn of California, S. F. Prouty of
Iowa and L. C. Dyer and Richard Bar-
tholdt of St. Louis.

J. Thomas Heflin of Alabama, decid-
ed he could not make the trip.

Mr. Borland, who represents the Kan-
sas City district, will substitute for
Collier of Mississippi and Mr. Linthi-
cum for Covington of Maryland. Messrs.
Cullop, Linthicum, Kahn and Prouty
are "old members."

Immediately after the dedication cere-
mony Senator Kenyon will leave St.
Louis for a visit to Iowa and Senator
Hughes will go to Fort Smith, Ark., as
the guest of former Congressman Gre-

CARNEGIE I FOR P C

Other Distinguished
ing—Lineal Descen-
veil Jefferson

Distinguished guests
ipate in the dedication
Memorial building, the
Jefferson statue and th
of the Fourth Americ
gress already are arriv

Andrew Carnegie, who
address Thursday aftern
sion of the Peace Congr
to reach St. Louis to-m
or Thursday morning.
companied by Mrs. Carn
be the guests while in
Robert S. Brookings at
Lindell boulevard.

Miss Natalie Norton of
a lineal descendant of T
son, was chosen yesterda
Jefferson statue. Miss
daughter of Porter Nort

The first of the Peace
monies, which will contin
the week, will be to-nigh
don Memorial Auditorium
Missouri oratorical cont
tercollegiate Peace Assoc

Former Judge Selden F
preside. A student from
Missouri colleges will
first prize of \$75 is offer

tercollegiate Peace Assoc
second prize of \$50 is o
American Peace Congress

Central College, at Fax
represented by Edward
who will speak on "Our
Peace." John Leo Tierne
University will speak on
Peace." George C. Wilson

iversity of Missouri will sp
Too, Are Brothers."

Washington University
sented by R. J. Puchsch
cration is entitled "The
Honor of Nations." West
lege, at Fulton, is repres
Poage Dalton. His subject
mand for International F
liam Jewell College, at Lib
represented by Frank R. B
will have for his subject "T
Total of Wretchedness."

More than 1,000 delega
sections of the country ar
distinguished persons from at
tend the sessions. Congre
ard Bartholdt of St. Louis
at the meetings.

United States Senator J
will be one of the congr

Stock No. 10.

Balsam Fir.

SCAFFOLD, 1

Two Others, Working
Get Fractured Ribs
Broken Leg.

VICTIMS CARRIED UP

Workmen Fall Thirty
and Cries Bring For

to Their Aid.

One man was injured prob-

ably and two others seriously in-

jured at the William Graver

pany. Second and Rutter st-

way yesterday afternoon. The

Joseph Rerrie, who had be-

but a short while, and who

was unknown to his fellow

unconscious at the City Hospi-

fractured skull and internal

James Dixon, 33 years of

Shenandoah avenue, had

broken, and the left leg of J

in two places. The two

taken to St. Mary's Infirma-

The three men were at w

scaffold inside a big steel t

they were building.

Enos Konoskia, the fore-

their cries, but could not

until the other men, under

tion, brought ladders and jo

inside the tank. They were

up a line of men formed on

der.

ED: Can you take a hint? You ca

at Loftis' for \$1 a week, 2d floor, 301

39 DIVORCES ARE C

Seven New Suits for Martine

Are Filled.

Divorces Granted yesterday

Dudley E. from Mary M. W

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including 500 for spec
6,200; ordinary
700 American. Re
can. Futures open
auzet.

per 100 lbs.; old rope, manilla \$1.50; com-
mon 40c. Rubber—No. 8; arctics—trimmed
\$5.00; untrimmed \$3.75.

Brew stock steers sold, Bullock
Choice feeders were scarce
and steady. Cows made up
for two bunches of calves
sold, prices ranging from \$3.80 to \$5.60
per cwt. for two bunches of calves
sold, prices ranging from \$1.00 to \$1.50.

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and steady. Cows made up
for two bunches of calves
sold, prices ranging from \$3.80 to \$5.60
per cwt. for two bunches of calves
sold, prices ranging from \$1.00 to \$1.50.

Stock No. 7.

Lodgepole Pine. --- California.

ers want-
d and O
hester Av.

news service.
to \$800 per
I. White Supp
Kansas City.

en. Call early
rooms with
NEBRASKA.

OLIVE. 1810-2 nice unfurnished
Grand 3038R.

OLIVE. 1424-Large room; housekeeping;
smaller room; also hall room.

OLIVE. 3117-Small room; suitable for
light housekeeping; \$1.75; also parlor.

OLIVE. 1807A-Clean rooms for private
rooms or light housekeeping; \$2.

OLIVE. 4123A-Nearly furnished room;
bath; free Bell phone; private family.

OLIVE. 4410-Pleasant room; well fur-
nished; for gentlemen; southern exposure;

OLIVE. 4288-Nearly furnished, connect-
ing rooms; table for sleeping; all conven-

OLIVE. 4610-Rooms complete for house-
keeping; kitchenette with running water;

PAGE. 4025-2 nice rooms; for gentlemen
or light housekeeping; 2d floor; southern expo-

PAPIN. 1649-Comfortable, well-furnished
outside rooms; conveniences; large yard.

PARTY owning home will furnish house-
keeping suite for desirable couple \$100 west.

ROOMS. Steam heated; running water;
elegant residence; locally unsurpassed.

Grand 1013.
man and wife; privileges; furnished, for
Forest 1808.

M'PHERSON. 4057-Front, 2d-story, also
single room; private home; all conveniences.
Lindell 4917R.

M'PHERSON. 407A-Well-furnished,
large, light rooms; steam heat; continuous
hot water; Olive car.

MORGAN. 3338-Nicely furnished, con-
necting rooms on 1st floor for light house-
keeping; reasonable. Bonmont 2405.

MORRISON. 1211-Nicely furnished, large
front rooms; housekeeping; \$4 week. Kas.

MORRISON. 1031-Single front room; also
connecting housekeeping rooms; bath, gas;
all conveniences.

NEBRASKA. 1810-2 nice unfurnished
rooms with heat and light; reasonable.
Grand 3038R.

OLIVE. 1424-Large room; housekeeping;
smaller room; also hall room.

OLIVE. 3117-Small room; suitable for
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outside rooms; conveniences; large yard.

PARTY owning home will furnish house-
keeping suite for desirable couple \$100 west.

St. Louis 1808.

Apply rear
men; wages
Bldg.; send

also; wages
side rooms; gentlemen or housekeeping; gas.

TWELFTH. 201 N.-Newly furnished out-
side rooms; gentlemen or housekeeping; gas.

VISTA. 3206A-Nearly furnished large
room and hall room; all conveniences.

VISTA. 3311-Nicely furnished rooms; con-
venient to Park and Grand cars; for gentle-

positions sal-
C. Rocher-

ly at 2752
four store.

ly at 906
ber shop;

for barber
rooms;

WASHINGTON. 3029-Newly furnished
front and back parlors; also 2d-floor rooms;

hot bath.
WASHINGTON. 2843-Front room; \$2.33;

apply 2308
front room; single or en suite; southern ex-

WASHINGTON. 4410-Newly furnished
water; phone.

WASHINGTON. 3337-1 nicely furnished
front room; also hall room; hot and cold

WASHINGTON. 4156-2 connecting house-
keeping rooms; also 2d-floor room; all conven-

WEST. 1199-Large room; private fam-
ily conveniences; 2d floor. B apart-

ble; Cabany 2763.

room; family; young lady employed; reasona-

VON VERSEN. 5800 Block-3d-floor front
room; light; all conveniences; pri-

ly at 2752
room for 2 gentlemen or couple. Cabany

VON VERSEN. 5871A-Large south front
room; for 2 gentlemen or couple. Cabany

WASHINGTON. 2843-Front room; \$2.33;

apply 2308
front room; single or en suite; southern ex-

WASHINGTON. 4410-Newly furnished
water; phone.

WASHINGTON. 3337-1 nicely furnished
front room; also hall room; hot and cold

WASHINGTON. 4156-2 connecting house-
keeping rooms; also 2d-floor room; all conven-

WEST. 1199-Large room; private fam-
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ly at 2752
room for 2 gentlemen or couple. Cabany

VON VERSEN. 5871A-Large south front
room; for 2 gentlemen or couple. Cabany

SEVENHENTH. 1529A N.-Nicely fur-
nished front room, with or without board;
private family.

THE MOZART. 3517 Lucas (Just East of
Grand) Newly furnished front rooms for
day or week; board optional; especially low

rates for the summer.

TWO gentlemen or 2 ladies employed can
secure beautifully furnished front room with
excellent board, in modern front and apart-

ment; price reasonable. Forest 986.

VON VERSEN. 5042-Beautifully fur-
nished suite; also large southern room; fine
location; excellent table; private. Forest

1344R.

WASHINGTON. 3332-1 single room, nice-
ly furnished, with board; furnace heat.

WASHINGTON. 3963-2d-floor front for 2
gentlemen; middle room; southern exposure;
excellent board.

WASHINGTON. 3206-Nicely furnished
large cool southern-exposed front room;
reasonable; home cooking.

WASHINGTON. 4049-2d-floor front room;
all conveniences; running water; excellent
board.

WASHINGTON. 3841-Large, nicely fur-
nished front room; 3 ladies or gentlemen;
first-class board; terms reasonable.

WASHINGTON. 4004-Very desirable
rooms with excellent board; rates reason-
able. Monroe 2539L.

WASHINGTON. 4049-2d-floor front room; run-
ning water; extra large side room; excellent
board for couple.

WASHINGTON. 2630-Nicely furnished
rooms and board; home cooking; all modern
conveniences; from \$4.50 up.

WASHINGTON B. 3101-Nicely furnished
rooms; conveniences; board optional. Phone
Central 9335R.

WAVERLY. 1744-Nice room; electric
light; continuous hot water; convenient to
cars; reasonable; board optional.

WEST BELLE. 1666-Nicely furnished rooms
with excellent board; must be seen to ap-
preciate.

WEST PINE BL. 4132-Neat, comfortable,
clean, light rooms; superior table; electric
lights; phone.

WEST PINE. 4108-Large, unusually
bright 3d-floor front and southern-exposed
rooms, with board.

WESTMINSTER. 3908-Large 2d-story
front, also other rooms; excellent board;
phone; electric lights.

WESTMINSTER. 3818-Nicely furnished,
large rooms; board optional; all conven-
iences; free phone; Olive car.

OLD GOLD AND SILVER.

DIAMONDS for old gold and silver. We will accept
your old gold jewelry at 25 per cent above market
price and apply entire amount on the purchase of a
diamond at discount prices. Pay balance monthly.

LOTUS Bros. & Co., 2d floor, 308 N. 6th st.

WATCHES, DIAMONDS, JEWELRY.

Best watches, a diamond. No
other woman wears a diamond. No
diamonds worn. Now is the time to secure
one of our splendid bargains.

ON
while you are paying small amounts
toward the purchase of a handsome ring

CREDIT
diamonds and watches. LOTUS BROS. & CO., 2d
floor, 308 N. 6th st.

BUSINESS FOR SALE.

BARBER shop; cheap; leaving town. 8643
College av.

BARBER shop; cheap for cash. Call 1405
Franklin.

BARBER shop for sale on account of ill-
health. 1832 S. 14th.

BARBER shop; good location; doing time
business; leaving city. 1018 Geyer av.

HARBER shop; two chairs; living-room; pa-
Good-paying shop; \$100 down. Call 2108 N.

CONFECTIONERY
candies, cigars, sta-
tionery, laundry, etc. 20 N. 10th.

on time
7 days.

WED.

ROLLING

over 16

on time

7 days.

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FOLK TALKS ON JAP QUESTION

Declares States Rights Are Not Involved in Controversy.

OMAHA, Neb., April 28.—Former Gov. Joseph W. Folk of Missouri tonight delivered the commencement address to the graduating class of the Law School of Creighton University.

In an interview Gov. Folk discussed the Japanese question in California, said States' rights were not involved in the controversy, since everything pertaining to treaty rights had been ceded to the National Government when the legislation was adopted.

Auto Hits Car, Two Bruised.

The impact of a heavy automobile truck which collided with a Cass avenue car at St. Louis and Lambdin avenues derailed the car and threw the passengers from their seats. The automobile was driven by Ludwig Moog, 6800 Florissant avenue. Mrs. J. E. Mullin, 4772 Green avenue, and Patronman David Kemp, passengers on the car, were bruised.

OPENING OF JEFFERSON MEMORIAL BUILDING

TO-MORROW

With the official opening of this handsome building, another spacious artistic edifice is thrown open to the St. Louis public. Extensive preparations are being made for this event. The principal address of the day will be delivered by William M. Thornton of the University of Virginia, who has made a life's study of the history of Thomas Jefferson.

A sight of the building itself is worth going miles to see. Architecturally it's a thing of beauty. The decorations and furnishings have been chosen with great care and taste. When viewing the interior of the building, don't fail to take notice of the elegance with which the Assembly Hall, Second Floor, East Hall, is furnished. This room was furnished by the St. Louis Chapter of the D. A. R. One hundred and fifty solid mahogany chairs in this hall were purchased from the

"I feel that in the discussion of late of the social evil there has been overlooked one of the chief causes, the absence of attractions that have the proper appeal to our pleasure-loving youth. It is human nature to want diversion. We cannot hope to eradicate that desire in the heart of every young man and woman, boy and girl. We deplore the existence of the cheap theaters, dance halls and summer gardens; but what do we offer in lieu thereof?"

Suggests Branch Galleries.

"We may divert this energy into other channels. To me it is most criminal the way we neglect our young people. True, we provide schools, and many parents are often glad to be rid of their children for this period. Their homes are in many instances simply places where they eat and sleep.

"The children go out on the street and fall an easy prey to the dealers in crime. The churches are closed except on two nights of the week. Our congregations, if I am not mistaken, are principally made up of the same people at every service. What is being done to reach the thousands of young people who do not go to church?"

As a means of reaching the people with the Art Museum, Mr. Holland suggested branch galleries where exhibitions could be held and musical entertainments given.

Pansy Plants 25c Per Dozen

This week only at our Greenhouses, Taylor and St. Louis, Grimm & Gorly.

To Show Lutheran School Work.

An exhibit of the school work of Lutheran institutions in St. Louis will open in Walther College, Park avenue and Benton place, to-day. The exhibition will close Friday with an entertaining address by Prof. A. Miller of the Teachers' Seminary at Addison, Ill.

Not how cheap, but how fine, for the least money, is my motto. Suits, \$30 up. Hesse, tailor, 8, e. cor. Fourth and Pine.

Mrs. C. W. Holcampa Gets Divorce.

Probate Judge Charles W. Holcampa did not contest the divorce suit of his wife, Mrs. Nellie F. Holcampa, who yesterday obtained a divorce and the restoration of her former name. Mrs. Holcampa testified her husband began to grow cold to her four years ago. For three years before their separation they lived apart, she stated. The couple were married September 23, 1903.

"DONALD: The other girls have diamond rings. You can get me one at Lotz Bros. & Co., 2d floor, 308 N. 6th st., on credit and we'll be married."

Campbell in New Firm. The firm of Hollingshead & Campbell, 6 Nassau street, New York City, will expire by limitation April 30, and since John P. Hollingshead has retired a co-

UNIFORM CO

MADE OF MILD—FRAGRANT H

Prutrock-Litton Furniture Co.

from the chairs in this hall were purchased from the

This room was furnished by the St. Louis Chapter of the D. A. R. One hundred and fifty solid mahogany chairs in this hall were purchased from the

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Stock No. 8.

Red Fir.

Arrives in St. Louis Miss Edwine Thornburgh

Stock No. 8.

JOHNSON DEFI
URGES JAP L
BRYAN CONF

Red Fir
Governor of California
State Is Acting Wil
Rights.

TWO HOUSES MEET I
AFTER SECRETARY

Washington and Arizon
sue in Secret Ses
Assembly.

SACRAMENTO, Cal., Apr. 10.—The second executive session of the California Assembly, which opened at 10 o'clock this afternoon, Johnson practically defied the administration and made a statement which some of the members regarded as an insult to the federal authorities.

He reiterated that California has no purpose doing anything in the way of antialien legislation more restrictive against the Japanese than the Federal Government had enacted for.

It is reported that the Governor remarked that the administration would be justified in going to the courts to stop its proposed antialien legislation.

Stating his position to the Governor, Johnson said, in part:

"The bill proposed for passage by the California Legislature can't be justified on the basis of criticism from the national administration, nor from any foreign source. Here in California it is not a question of whether the Japanese take offense at what we do, but whether we give that Government cause for offense.

"I do not believe that the law prohibiting land ownership by aliens who are ineligible for citizenship gives the Japanese just cause for offense.

"If their dignity is threatened, they should have protested when the United States and Arizona passed laws that which we now propose.

J.C. STRAUSS
PORTRAIT.

MISS
EDWINE
THORNBURGH

to that Spring Suit matter, size up our goodly window showing.

We'll warrant that you walk into our shop and say, "Measure me." Prices \$27.50 to \$50.

McCarthy-Evans-
n Arx—Tailors
Olive Street

"The Post Office Is Opposite"

Your Watch, or Jewelry Repairing?

Bring your repair work to this store and have the complete satisfaction of guaranteed work by expert workmen, and quick service.

JACCARD'S
Broadway at Locust

communicated to him this afternoon after listening to you have had to say.

Laminetti attempted to make attack upon Gov. Johnson, criticised for not favoring the two years ago, but was a point of order, and the adjourned.

met again at the call of the officers of both houses when-tary Bryan shall indicate as received further information.

Bryan arrived in Sacramento this morning. With his plans were laid for an immediate, and shortly after 11 the first session of the conference.

Bryan reaffirmed the State's act in a manner it saw fit, stated several alternatives to a bill restricting aliens to citizenship," basing his on the broad foundation of these alternatives, in the which they were suggested, are

fornia in their efforts to prevent these aliens acquiring land."

Senator Sisson discussed points of international law involved in the dispute and declared that California is endeavoring to do only what Japan had done.

"If Japan threatens us with war what would she do when millions of her citizens have acquired land in our country?" he said.

"I lay down the proposition that an alien population holding land within our borders would be a fixed and constant menace.

"I think it the duty of every loyal citizen of all our States to stand for California and her rights in this fight for her own citizens and their descendants."

Wearied with a week of routine tariff debate, members paid close attention to Mr. Sisson's argument and his speech was frequently interrupted by applause.

VISCOUNT IS NOT COMING.

Japanese Parties, However, Will Send Representatives to United States.

TOKIO, Japan, April 28.—The report that Viscount Kentaro Kaneke, Privy Councillor, is going to Sacramento in connection with the pending alien land ownership legislation is untrue, but the Seiyukai (constitutional) and Kuminto (opposition) parties are dispatching representatives to California to investigate the situation.

The official view is more hopeful owing to Secretary Bryan's mission, but public opinion still insists that the present is the most suitable moment to settle the whole American-Japanese question and thus prevent a recurrence of similar disputes.

An inspired article in the newspaper Asahi explains that the delay in putting in force the Japanese foreign land ownership bill of 1910 has been due to the discovery of imperfections, and the long list of these cited indicates that

so be forfeited and his out of business.

He called attention to legislation in other States companies chartered in from doing business in

He said that the risk would become so bad at companies had withdrawn entailed by those companies wrote policies here would ship on the policy holders States, who would have increased premiums the es in Missouri.

He said it would be in few companies to carry insurance business of the declared that in Illinois at which have no insurance similar to the Orr state for insurance are considered than in Missouri.

At the meeting were chairman of the committee by the committees of the which met last week to way out of the insurance Ernst A. Hildenbrandt, Real Estate Exchange, pen, George D. Markha Thomas.

Referendum Now the Insurance and business the city have looked bankers' meeting with promising of results. reach an agreement and the Governor to consider by insurance men and posed by business interest to leave the only hope of Orr laws in the referendum.

Local insurance men pleased than grieved at the Supreme Court to companies from cancelling their books.

They pointed out that bunal also refused to companies from suspending its refusal to compel the writing insurance.

This action, they said, official sanction to the companies in suspending the State.

Insurance men declare insured persons are to their insurance for a having new policies with their property for a short expectation that within some way out of the difficulty found.

The American Central terday notified its St. L. cease writing business County and to take over handle too much continuing near to each other in districts.

Committee to the
The committee of the members of business of

Stock No. 9.

Hemlock.

[illegible]

Stock No. 11.

Tamarack.

their daughter, Miss Marguerite Benson, whose marriage to Lieut. Bert P. Strellinger, U. S. A., will take place this evening. The guests were limited to members of the two immediate families.

The engagement of Miss Luella McCain, daughter of Dr. and Mrs. L. C. McCain of 5190 Maple avenue, to David Swing has just been announced. The wedding will take place early in June.

Mr. and Mrs. E. J. Elmer and their daughter, Miss Beatrix Elmer, who have been traveling in California the last six weeks, are in San Francisco and will go early next month for a tour through the Yosemite Valley. They expect to return home about June 1.

Mrs. Herbert L. Parker of Washington terrace will give a large bridge party this afternoon at the Bellerive Country Club.

Mr. and Mrs. Charles R. Peddle and their family will take possession of their new home at 5355 Berlin avenue tomorrow.

Mrs. Frank Blackburn of Cincinnati, who has been visiting Mrs. Arthur N. Eger, the last fortnight, departed yesterday to join her husband in their home near Medford, Ore., for the summer.

Miss Mildred E. McPherson has sent out invitations for her graduation reception in the department of expression in Knox Hall, which she will give Saturday evening. All the numbers on the programme will be her own composition.

Mr. Thomas Ray of 6039 Berlin avenue is entertaining Mrs. John R. Walker of Kansas City as her guest. Mrs. Walker has come to St. Louis as a delegate to the Peace Congress, and as national vice president of the Daughters of the American Revolution will take part in the dedication of the Jefferson Memorial.

Miss Jane Taylor, daughter of Mr. and Mrs. Daniel G. Taylor, has gone to Parkville, Mo., to visit Miss Catherine Cameron, daughter of Mr. and Mrs. Edward C. Dameron, whose country home is there.

Mrs. C. Spencer Meredith, who recently returned from visiting her sister, Mrs. Charles P. Briggs, in Calvert, Tex., departed Monday evening for Chicago to pass several weeks with her son and daughter-in-law, Mr. and Mrs. C. Spencer Meredith II.

Mr. and Mrs. Clarence Link of Bedford, Ind., are visiting Mr. Link's parents, Mr. and Mrs. Theodore C. Link.

party today adopted resolutions affirming their loyalty to the initiative and referendum, the recall and the review of judicial decisions.

It also opposed "unequivocally and unreservedly any amalgamation with the discredited Republican party which under recent dishonest leadership has failed to carry out the precepts of Abraham Lincoln and the other honorable founders of the one known party."

"We favor the nomination by the Progressives of candidates for all offices, national, State and congressional, legislative, county and local, except where nonpartisan local elections are or can be provided for by statute and secured on honorable and fair terms by nonpartisan co-operation of the several political parties," the report continues.

"We pledge ourselves to the enactment of legislation which will divorce all county, municipal and other local offices from partisan politics, to the end that such local campaigns may be conducted on local and not on national or State issues."

The resolutions also dealt with conditions in the State Legislature.

The House Public Utilities Committee held its first meeting and listed to arguments of independent concerns in opposition to the double control planned in most of the measures before the committee.

The independent telephone people also objected to proposed valuation schemes which do not allow the valuing of a franchise originally obtained from the people.

The telephone men objected likewise to the city-control feature of the administration bill, for the reason, they said, that half of the number of subscribers were in the cities, and the other half in the rural districts.

City control would fix the rate for city subscribers, but the city could not

EYES

If you eyes as there is as to w get you

Stock No. 11.

Tamarack.

govern the r ers.

By a vote of House adopted Committee, w question of a raised on the f the question w tee when the der considerat

The Senate, Hurburgh's and Representative was advanced House. As am on Labor and bill provides a a week for per of age whose than \$150.

PROTESTING

Sympathizing

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Kum, a youn suicide by sho test against th California unf

He came from exhibited an e the Western S

R — **To Women Seeking Health and**

For those ills peculiar to women Dr recommends his "Favorite Prescri

"THE ONE REM

A medicine prepared by regular graduated p ual experience in treating woman's diseases—t to work in harmony with the most delicate femi

All medicine dealers have sold it with sat tomers for the past 40 years. It is now obtain sugar-coated tablet form at the drug store—or stamps for a trial box, to Buffalo.

Every woman may write fully and confidentially Invalids' Hotel and Surgical Institute, Buffalo, N. sure that her case will receive careful, conscientio consideration, and that experienced medical advice to her absolutely free.

CUTARI REFUSED

ill Firm as
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Wednesday.)—A
Daily Telegraph
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HAIR, OR BEAUTIFUL, TRACTIVE--CHOOSE, MADAM!

Mixed With
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bout 50 cents.
"Wyeth's"
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is the hair so

son Herbst gives for his thert, which
he willingly admits. All during his
married life of fifteen years, he says,
he has had to struggle along on a sal-
ary averaging between \$10 and \$15 a
week.

At first he intended to pay the mon-
ey back, he said, and took but small
amounts of \$5 or \$10. Later, however,
he became bolder and finally realized
that he would be unable to cover up
the deficiency much longer.

Then, he said, he confessed to his
wife, who advised him to make a clean
breast of the matter to the lodge of-
ficers, and about three weeks ago he
laid the matter before them, promising
to repay the money.

Relatives say that for several months
Mrs. Herbst has been ill, and they be-
lieve that much of the money went to
pay her doctor's bills and to buy medi-
cine.

Gymnastics for Home Orphans.

An exhibition of gymnastics and
marching was given last evening in the
Christian Orphans' Home, 2955 North
Euclid avenue, under the direction of
Central Y. M. C. A. and W. H. Wissman,
instructor. Among those present were
Mrs. S. H. Thompson, president of the
Board of Managers; Mrs. W. D. Patter-
son, chairman of the Gymnastics Com-
mittee; Mrs. D. Williams, chairman of
the Mission Committee, and Mr. and
Mrs. W. Cree. Music was rendered by
Mrs. Dean Jones.

Minister Robbed on Car.

Rev. C. T. Collyer of Nashville, Tenn.,
an evangelist, was robbed of a wallet
containing \$75 and return tickets to
Nashville last evening by pickpockets.
He was about to board a car at Thir-
teenth and Olive streets when he was
jostled by a crowd. When he looked
for his purse it was gone.

eral committee that the referend-
um invoked as a means of evading
mission to the Orr insurance laws.

In suspending the objectionable
through the referendum, the com-
tee believes, lies the only hope of
ing the large insurance companies
Missouri and keeping business up
stable foundation.

RISK MEN TO STAY, MANY WR

Revelle Notified by 15 or 16 Con-
They'll Not Quit the State.

JEFFERSON CITY, Mo., April 29
strong indication of a break in
ranks of the insurance companies c
to the Insurance Department to-da-
letters from fifteen or sixteen fore-
fire companies.

The companies said they had no
tention whatever of suspending op-
tions in Missouri to-morrow or
other time and will continue to
any risks offered to them.

The first communications came f
the Standard Fire Insurance Comp
of Hartford, Conn.; Buffalo Germa
Buffalo, N. Y.; Iowa State of Keol
Underwriters' American Lloyds of
York and Colonial Assurance Comp
of New York.

All that wrote are members el
of the Western Union, which me
Philadelphia, or the Western Bur
which met at Pittsburg.

The Insurance Department is ex-
ing more letters. With those that
repudiated the agreements, the
home stock fire companies and
twenty-six mutuals, the State will
be entirely without protection sh
the companies proceed to carry
their threats.

The five Missouri stock fire cor-
nies, which could not suspend, eve
they wanted to do so, follow: An-
can Central of St. Louis, Citizens
St. Louis, Individual Fire Underwr
of St. Louis, Central Union Fire C
pany of Kansas City, Equity Fire
insurance Company of Kansas City.

The foreign companies that do
suspend will be eliminated from
proceedings in the Supreme Court.

There is no doubt that criminal
ceedings will be instituted by Atto-
General Barker should the emerge
for such action arise.

He has taken steps to get the na-
of the officers of the companies
were represented in the Philadel-
and Pittsburg meetings, to lay be-
the Cole County Grand Jury.

CONNOR DEPOSITIONS HALT

Injunction Stops Inquiry Into Me-
Condition of Mrs. Georgiana Miller

Depositions to have been taken
terday for use in the inquiry as to
mental condition of Mrs. George
Miller of 5435 Maple avenue were
vented by an injunction suit bro-
in the interest of Mrs. Miller.
The depositions were to have t

Stock No. 12.

Tamarack.

SALE DAY—At Elroy Deery Bridge
 Sales at Residences or Specially. Cards
 Vanced
AT GRAND AND LACELLE
 IN THE LEONORI ART ROOM
 Fine Furniture, Oriental Rugs, e
 Angers, China, Silverware, Linens, e
 Auction this Wednesday Morning
 o'clock. R. U. LEONORI AUCTION
 STORAGE Co., Auctioneers.

AMUSEMENTS.
SHUBERT MATINEE TO-DAY
GERTRUDE HOFFMANN BRO P.
NEW BIG REVUE—150 People—
 PRICES: 25c, 50c, 75c, \$1.00, \$1.50.
COLUMBIA REAL VAUDEVILLE
 2:15—TWICE DAILY
HEDWIG REIGNER
 EDISON'S TALKING MOTION PICT
 The Bogammy Troupe
 Ed. Blondell & Co.
 Jack H.
 Ethel May Barker
 Snyder & B.
 Prices 15-50c.
AMERICAN 25c MATINEE TO
 THE GREATEST LOVE STORY EVER Y
 10-NIGHT, 98-
'ONE DAY'
 The Sequel to the Sensational Play "Three
 10c—TALBOT'S—
HIPPODROME
 Two Big Headline Acts
"THE SUBSTRAN WINNER"
 and
"SCROOGE"
 Also—
 The Bim
 Nurette
 Carl Ral
 Peerless
 Photographs.
 Continuous from 11 A. M. to 11
 3000 Seats.

GRAND OPERA HOUSE
 Market St. Bet. Broadway and
 14—ACTS IN EVERY SHOW
HICKEY'S COMEDY CH
EDISON'S TALKING PICT
 The Police Inspector
 3 Musical Kings
 M. L. Moore
 Award Bress.
 Egan, Boyce an
 Peltie Sisters
 Martin Von B
 Seymour Hand
 Tobham and

KINEMACOLOR
 Continuous from 11 A. M. to 11
 10c—2 SHOWS ONE ADMISSIO
EMPIRESS THEA
 Offered West of Grand
 Chicago, Illinois
 3:00 P. M. 2:30 P. M. 10 P. M.
 10—ADMISSION 20

DELMAR GARD

PENING IN EXCHANGE
 STEAMER GREY EAGLE
 W. H. THORWEGGEN, Master.
 4, to Allen and Illinois River, Street 10 A. M. Re-
 and Trip, 50c. (Leave on Monday and Thursday)
 /ENING, MAY 21—And on Tuesday and Thursday.
 P. M. Returns 11 P. M. Round Trip, 50c.
 Organizations May Secure Dates by Applying in Office.
 Central 860.

of beef—prove it by your doctor.

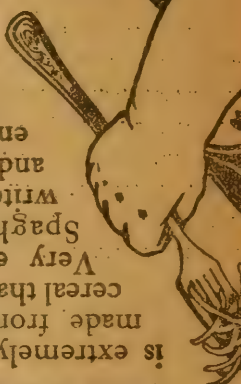
FAUST

SPAGHETTI

is extremely rich in gluten, being made from Durum wheat, the cereal that ranks high in protein. Very easily digested is Faust Spaghetti. Savory, too—write for free recipe book and see how many different ways this strengthening building food can be served.

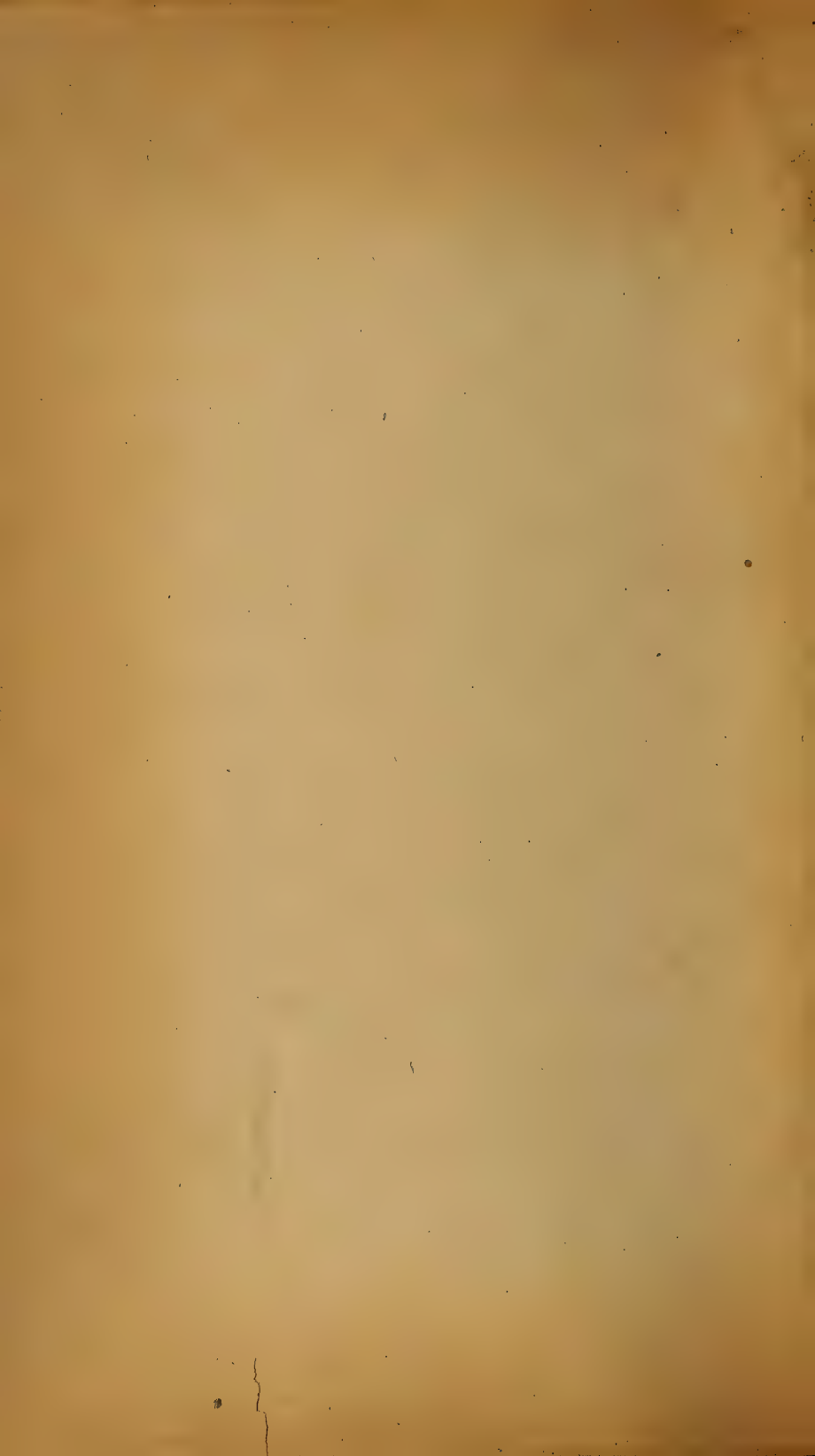
At all grocers,
5c and 10c packages

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ST. LOUIS,
MO.



Stock No. 13.

Noble Fir.



WARD LINE O. S. Mail Steamships, Havana-Nassau, Havanna.

(Ship) of SYDNEY SHORE LTD. sailing every
 two weeks.
 Round Trip
 \$1000
 (First Class)
 Round trip, second class \$900
 And round Java, China, Japan
 and round the world. Send for folder.
 COMPANIA TRASATLANTICA
 (Registered Royal Mail)
 For (C.A.I.) and BAHIGUEL A.

48: price \$1,750.
Phone, 3247—
enger Touring Car,
S. 212 West 43d.
Fine Daily and

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REPUBLICAN
918 Report Sh
to R
John A. Toppin
Public Iron and
ention in the cor
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Americ
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Establish any off
Apply at any offi
tional Express Co

DIVIDENDS
GREENE G
G
42 Broadway, Ne
No. 6 of 1% on th
The directors hav
dividend of March 2,
favorable to the
close of business I
will not close.
J. W. A

SOUTHERN
30 Church Street,
A DIVIDEND OF
PERCENT (2½%) has
been declared on Fri
day, April 24, 1914
at the close of busi

THE ASSOCIATED
Hobbs.
The regular quar
TERLY DIVIDEND OF
SEVEN PER CENT
(7%) has been declar
ed on April 27, 1902, will
be paid on May 27, 1914, to
holders of record on
April 27, 1914. To
close of business I
Associated Merchants
THE ADAMS
No. 71 Broadway,
The transfer be
the morning of Ma
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A quarterly divi
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of United Dr G
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Stock No.14.

Alpine Fir.

Lifting of Arms Embargo Commended by a Senator

Sheppard, of Texas, Says That President's Action Was Prompted by Highest Considerations of Justice and Humanity.

NOT EVEN HUERTA HAS COME ALPINE

HERALD BUREAU,
No. 1,502 H STREET, N. W.,
WASHINGTON, D. C., Friday.
Morris Sheppard, democrat, of who for months has been urging on of the belligerent rights of the constitutionalists, to-day strongly President Wilson's action in raising embargo on arms.

General Huerta had complained of the embargo was a violation of principle of international law, he in effect was to place the United States in an attitude of complete neu-

trality. Wilson's action in lifting the embargo was prompted by the highest considerations of justice and humanity," said Sheppard. "Let it be remembered that the embargo was originally imposed by enemies in North Mexico. Huerta fell his friends and fellow-revolutionists. Their principal stronghold was also North Mexico. The lifting of the embargo was a disfavor against them because it deprived them of practically their only source of arms and ammunition. Huerta, who controlled the sea-land import arms from many other

an act which originally benefitted the revolutionist cause, the cause of liberty in Mexico, became an injury after champions, the followers of Huerta. As a result hundreds of patriots who believed with Carranza and who could not obtain arms often stand in line on a battle field to get fire from the enemy, waiting for the arms of their soldier brethren and thus enter the fight. The patriots were compelled to fashion their cannon from the axles of wheels and locomotives. As a result of those who stood with Carranza for a freedom and right would face machine guns and rifles of Huerta and arrows as their only

It became evident that the retention of the embargo was merely prolonging the war and that the placing of the constitutionalists on an equal footing with the opponents in the matter of arms was the contest to a more rapid end and thereby end the confusion

of the Mexican masses for liberty and progress. His ideals are those of Washington, and his followers are imbued with the spirit of Concord and Valley Forge. It is his ambition to conduct this revolution along the lines of civilized warfare and to repress excesses of every kind. Conditions have made it difficult at times for him to do this, especially as his opponents show his own followers no consideration and no quarter. He should not be held responsible for the acts of irresponsible bandits, roaming at large over a vast and in many instances almost inaccessible territory."

REAR ADMIRAL MAYO ACTS ON SHOOTING

HERALD BUREAU,
No. 1,502 H STREET, N. W.,
WASHINGTON, D. C., Friday.

Rear Admiral Henry T. Mayo has sent word to the municipal authorities of Vera Cruz that they must assume responsibility for the shooting of his flag lieutenant, Lieutenant Arthur B. Cook. A report to the Navy Department confirmed the press reports of the shooting of Lieutenant Cook, but said that he had not been hurt. It is understood here that Rear Admiral Mayo meant, in his communication to the Mexican authorities, that he would expect them to prevent any recurrence of the affair. It is reported that the Vera Cruz police are looking for the assailant, but Mexicans here believe that there is little chance of finding him.

The State Department has been advised that the federal lieutenant and sergeant who were convicted of the murder of an American, Frank Smith, were put to death on February 11 by order of the military court. They were shot by a detachment of soldiers at the scene of the murder.

The Secretary of State, Mr. Bryan, today said that the European Powers had been advised of the intention to lift the embargo and that the reason given was that the Mexicans should be left free to settle their own affairs. This information was in confirmation of the press reports regarding the discussion of the Mexican situation in the German Reichstag yesterday. It is considered an important precedent for an American Secretary of State to declare against the right of American intervention in Latin America.

WOMAN BAFFLED

Miss Margaret Fox, 14, based in Ice on F

ABSENCE OF
FIR. INDICAT

Opening Into Which
or Been Thrown
Been C

[SPECIAL DESPATCH
HARRISON, N. Y.,
hours to-night the police
Coroner Alfred H. 1
county, worked in an
mystery surrounding
Margaret Fox, forty-
was found dead this
on her farm here. The
the well, which is two
only two feet in diam-
cased in ice. A hinged
covers the circular
closed after the woman
pushed down the shaft.

The baffling aspects
confronted the author
though the sides of the
hewn stone with rag-
out, so that in places
diameter than the su-
of twenty-four inch
bruises on the body,
over the well, when
back until it rests on

"If the woman fell
foremost," said Coroner
loss to know how she
contrived by her effort
or, otherwise, if it was
to close the trap after

Captain Andrew Mu-
son police, who has ch-
gation, subjected sever-
ous examination to-
ing enlightening facts
circumstances of the woman

Discovery of
Mrs. Fox, who leaves
at one time kept several
house, which is near
about a mile from the
Recently, however, the
one of the women

Defendant:
 Plaintiff:
 Plaintiff's Attorney:
 Address, No. 51 Chambers
 Manhattan.
 F—
 ons is served upon you by
 an order of Hon. James C.
 of the Supreme Court of the
 led the 2nd day of January,
 3rd day of January, 1914,
 the office of the clerk of
 at the County Court House,
 County of Kings, in said

EMIAH T. MAHONEY,
 Plaintiff's Attorney.
 Address, No. 51 Chambers
 Manhattan, City of New York.
 agate line Daily and

EMIAH T. MAHONEY,
 Attorney for Plaintiff.
 Address, 51 Chambers
 Manhattan, City of New York.
 agate line Daily and

PURCHASE OR EXCHANGE.

id for contents of houses,
 etc., Antiques, &c. JONES,
 Telephone, 8851—Harlem.

urniture, Planos, Antiques,
 getting my cash offer.
 place, 2298—Stuyvesant.
 ses, Planos, Carpets, An-
 ES, 155 East 125th. Tele-

s contents apartments, Fur-
 a-Brac, Carpets, Licens,
 MILLER, 104 West 122d.

s Furniture, Carpets, Bric-a-
 Silver, Works of Art, &c.
 ty place. Stuyvesant—1879.
 urniture, Planos, Antiques,
 University place. Phone,

ase or Exchange—50c.
 day; 50c. line Daily.

ACADEMIES.

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 57 ST. 57TH ST.
 Carnegie Hall. Instruction in
 a Dances. Tel., 540—Col.

N DANCES
 n. Boston, Tango, Maxire,
 Lessons, 1 to 10 P. M.
 STUDIO

15. 104 West 75th st.
 Tango, Hesitation, Boston,
 fined by personal attention.
 LORITA CHRISTIAN, 111
 cer.
 es—40c. agate line Sun-

COLLEGES, SCHOOLS.

Shorthand, Penmanship,
 and Stenotype Departments.

Day & Night Sessions.
 Call or write for Cata-
 logue.
 3d Street and Lenox Avenue.

in lessons given at your own
 terms very low. Write B.,

ages, Schools, &c.—20c.
 1 and Sunday.

WANTED—FEMALES.

ooks, &c.

wishes position, by day or
 E. Ziegler, care Lefkowitz,

arian, lately landed, wishes
 American family. Herbert,

erman woman, very compe-
 n private family; reference.

FILING clerk, young lady, German American;
 7 years' experience; references. GERLOCK,
 383 East 136th.

GOVERNESSES OR COMPANIONS, two young
 FRENCH ladies, well educated; Protestants.
 E. B. P., care Rev. O. D. Bluesser, 247 Bedford
 Park Boulevard (East 200th st.).

GOVERNESS or companion; young woman, speak-
 ing German, to children or elderly woman.
 Moderate, 180 Herald Harlem.

STENOGRAPHER, SIX YEARS' EX-
 PERIENCE; FORMER EMPLOY-
 ERS STATE, "EXCELLENT STENO-
 GRAPHER, POSSESSING INITI-
 ATIVE, COMMON SENSE." A X,
 140 HERALD.

STENOGRAPHER.—Refined young lady, 19, high
 school graduate; three years' experience, two
 with commercial house, one with official court
 stenographer; competent and trustworthy. R.
 Goodman, 147 West 142d st.

STENOGRAPHER, typewriter, office work,
 bright American girl age 20; experienced; refer-
 ences; wages \$12. C. R., 195 Berriman st.,
 Brooklyn. Phone, 1477 W. Cypress.

STENOGRAPHER, typist, German, English dic-
 tion translating, copying, desires home work;
 moderate. Miss Seamon, Trowmart Inn, 8th av.
 and 12th. Telephone, Chelsea—5254.

STENOGRAPHER, two years' experience, neat,
 willing, competent, \$9, \$10. W. W., 151 Herald
 Downtown.

STENOGRAPHER, office assistant, refined young
 lady; four years' experience; references; \$12.
 Ambitions, 407 Herald Downtown.

UNDERGRADUATE would care for invalid lady
 or weak child; refined; reference. C. W., 320
 Herald.

VISITING governess.—French language taught by
 Parisian; visiting or home. Flaques, 66 West
 107th.

Housekeepers and Janitresses.

HOUSEKEEPER.—Wanted, position as house-
 keeper, by educated German lady, about 40;
 speaks fluently German, English; best to be
 exchanged. G. E., 142 Ascension st., Passaic,
 N. J.

HOUSEKEEPER, educated, competent, experi-
 enced, respectable, honest German widow; takes
 full charge for adults in apartment; best man-
 agement; excellent city references. M. S., 1,658 3d
 av. (store).

HOUSEKEEPER.—A middle aged woman desires
 position as housekeeper for elderly couple. 124
 East 44th.

HELP WANTED—FEMALES.

BILL clerk or typewriter; must have at least two
 years' experience; wages \$12. Apply to Bill,
 P. O. box 1,721.

BOOKKEEPER.—Wanted, competent bookkeeper,
 stenographer to keep books, make invoices; able
 to take dictation; knowledge of import business;
 state salary wanted and give references. M. L.,
 130 Herald.

DRAPERS AND PINNERS,
 EXPERIENCED, ON LA-
 DIES' DRESSES. R. B. ROTH-
 FELD, 112 MADISON AV.,
 CORNER 30TH ST.

FOREWOMAN wanted for novelty curtain fac-
 tory; must be experienced; steady position; ap-
 ply with references, stating salary expected.
 The Green Mfg. Co., Bridgeport, Conn.

HOUSEWORK.—Wanted, French, German or
 Swedish woman, general housework in family
 two adults, small apartment; good home and
 wages; personal references. Write, stating age
 and wages, H. M. T., 268 Columbus av.

HOUSEWORK.—Experienced girl for general
 housework; best reference required. Maginnis,
 71 East 96th.

LADIES—Become diamond jewelry experts; splen-
 did positions with jewellers; pay \$25-\$75 weekly;
 free catalogue. Jewellers' Art School, 110 West
 40th.

LADIES, artistically inclined, to work for us
 in their homes. Apply by letter only, Kalos
 Mfg. Co., 48 West 27th st.

LORD & TAYLOR
 require

CAPABLE EXECUTIVE
 CONNECTION WITH
 PORATION IN MANAG
 CAPACITY; THOROU
 GANIZER AND EFFIC
 MAN; OUTSIDE I
 MAKES SALARY SECO
 CONSIDERATION
 ABILITY CAN BE I
 STRATED. A. G., 182 H

Capable bookkeeper
 wants position; unde
 German; can give high
 erence. W. M., 125
 Harlem.

CARETAKERS, reliable couple, for
 unfurnished house; excellent refer-
 ence, 445 East 52d.

CASHIER and cigar man; several ye
 ar experience; moderate salary; bond or ca
 Address C. Lancon, 1,422 Fulton st.,

CHAUFFEUR.—Young man, arrived
 about two months, 25 years old, wi
 as chauffeur and mechanic; city
 best reference. H. V., 133 West 45
 York.

CHAUFFEUR'S helper; well recom
 man, having taken mechanical le
 position with private family; can d
 al. Peter Nicolalde, 237 East 43
 York city.

CHAUFFEUR (27), married, wishes
 private family seven years' experi
 abstainer; references. Joseph Gross
 Pulaski st., Brooklyn.

CHAUFFEUR.—Wanted, position a
 commercial or private; can m
 license; ready for work. Box 947,
 av., Brooklyn.

CHAUFFEUR, mechanic; A1 machin
 repairs; private or commercial; be
 driving eight years; last position 61
 106, 1,318 2d av.

CHAUFFEUR wishes position with
 drive and repair any car; 10 years
 Frank Rosalia, 301 3d st., Brooklyn

CHAUFFEUR, mechanic; willing;
 years' experience; reference. Be
 20 Lawton st., Brooklyn.

CHAUFFEUR, 30, experienced, ma
 car; salary \$15; city or country
 Paroubek, 192 Potter av., Astoria.

CHAUFFEUR, English; five years dr
 York; excellent references; do
 E. K., 610 Herald.

CHEF wants position in hotel, elu
 rant. Emil Felix, 185 Poplar st.,
 N. J.

COACHMAN, 36 years of age, m
 family; A1 reference, thorough
 capable to take charge gentleman's
 stands plain gardening, also cows, i
 ing to go any part of country. Addr
 18 Nutman place, West Orange, N.

COLORÉD couple wish positions pr
 city, country. Felton, 171 West 8
 ment.

COMPETENT office man, five ye
 poration, department discontinued;
 reliable, Unitarian; moderate salary
 vice. Phone 6757—Columbus.

COOK, colored, wants evening plac
 11; good on short orders. Julius
 West 134th st.

COOK, first class (Chinese), 1 1/2 ye
 erence, Sidney, 161 West 36th st.

COST CLERK, SIX YEARS' EXPE
 ty cost, payroll and purchase rec
 803 Eckford st., Brooklyn, N. Y.

COUPLE (Holland); man underst
 motor boats, yachts, horses; hand
 and garden; wife understands to
 cessed. G. P., Arastel Hotel, 330
 Hoboken, N. J.

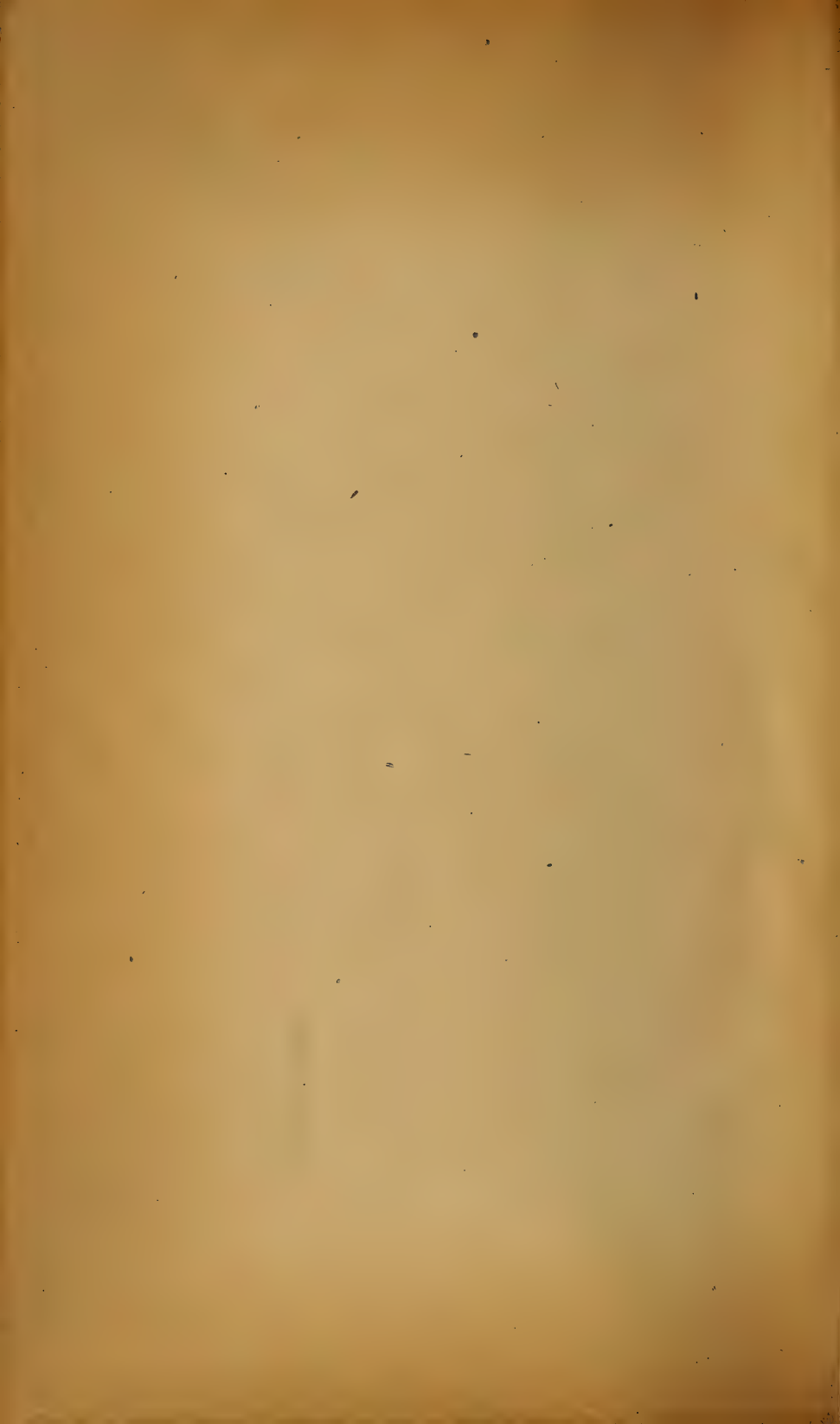
COUPLE, young, Austrian, refined;
 fish; butler, chambermaid or lat
 housekeeper; only landed; best cit
 Korkus, 330 East 87th.

COUPLE, Austrian, cook and but
 erences, wish private family possi
 290 Herald.

COUPLE, German; butler, house
 the cook, baker; good manager.
 East 57th.

Stock No. 15.

White Fir.



BAFFLES POL

Miss Margaret Fox's Body
Cased in Ice When Found
on Farm.

ABSENCE OF BRUISES
INDICATES A C

Opening Into Which She Had
Or Been Thrown Head First

Been Covered.

[SPECIAL DESPATCH TO THE H

HARRISON, N. Y., Friday.—Fo

hours to-night the police of Har

County, worked in an effort to

Margaret Fox, forty-five years

was found dead this morning

on her farm here. The body, he

the well, which is twenty feet

only two feet in diameter, was

cased in ice. A hinged wooden

covers the circular aperture

closed after the woman had t

pushed down the shaft.

The baffling aspects of the

of Arms Embargo

ended by a Senator

d, of Texas, Says That President's Action Was

ected by Highest Considerations of Jus-

tice and Humanity.

EVEN HUERTA HAS COMPLAINED

of the Mexican masses for liberty and

progress. His ideals are those of Wash-

ington, and his followers are imbued with

the spirit of Concord and Valley Forge.

It is his ambition to conduct this revolu-

tion along the lines of civilized warfare

and to repress excesses of every kind.

Conditions have made it difficult at times

for him to do this, especially as his op-

ponents show his own followers no consid-

eration and no quarter. He should not be

held responsible for the acts of irrespon-

sible bandits, roaming at large over a vast

REAR ADMIRAL MAYO

ACTS ON SHOOTING

HERALD BUREAU, N. Y., Friday.

No. 1,502 H STREET, N. W.

WASHINGTON, D. C., Friday.

Rear Admiral Henry T. Mayo has sent

word to the municipal authorities of Vera

Cruz that they must assume responsibility

for the shooting of his flag lieutenant.

Lieutenant Arthur B. Cook. A report to

the Navy Department confirmed the press

reports of the shooting of Lieutenant Cook,

but said that he had not been hurt. It is

understood here that Rear Admiral Mayo

meant, in his communication to the Mexi-

can authorities, that he would expect them

to prevent any recurrence of the affair. It

is reported that the Vera Cruz police are

looking for the assailant, but Mexicans

White Ink

Stock No. 13.

Arrows as their only

settles their own affairs. This information

was in confirmation of the press reports

regarding the discussion of the Mexican

situation in the German Reichstag yester-

day. It is considered an important prece-

dent that the retention of

as merely prolonging the

at the placing of the

an equal footing with

in the matter of arms

a contest to a more rapid

thereby end the confusion.

the chaos now prevalent

at Mexico as a much earlier

the reports asserting that General Villa

has been in the United States Army as-

Discovery of the

Mrs. Fox, who leaves no

at one time kept several

house, which is near V

Recently, however, there

one other occupant of the

tax certificate of a small c

of the house. He told the

went out last night to

one friends, leaving the

the United States Army as-

the reports asserting that General Villa

has been in the United States Army as-

the reports asserting that General Villa

has been in the United States Army as-

the reports asserting that General Villa

has been in the United States Army as-

the reports asserting that General Villa

has been in the United States Army as-

October 24, 1913.
JEREMIAH T. MAHONEY,
Plaintiff's Attorney.
and Post Office Address, No. 61 Chambers
Household of Manhattan.

—HARD—
proceeding summons on order of Hon. James C.
Ten, a Justice of the Supreme Court of the
New York, dated the 2nd day of January, 1914,
did die on the 3rd day of January, 1914,
47 of which, at the County Court House,
City of New York, County of Kings, in said
JEREMIAH T. MAHONEY
Attorney for Plaintiff.
Post Office Address, 61 Chambers
Household of Manhattan, City of New York

ED TO PURCHASE OR EX-
CHANGE.
Best prices paid for contents of HOMES,
Pianos, Carpets, Antiques, etc. Homeless,
12001st St., Telephone, 8851—Haitem.

one's self Furniture, Pianos, Antiques,
one before getting my cash offer.
100 University place, 2298—Stuyvesant.

one's houses, Pianos, Carpets, Antiques,
MILES, 155 East 125th St., Telephone,
694414.

cash prices Furniture, Carpets, Antiques,
20 University place, Stuyvesant—1879.
Pianos, Carpets, Antiques, etc. Homeless,
12001st St., Telephone, 8851—Haitem.

to Purchase or Exchange—40c.
one Sunday; 80c. one Daily.
DANCING ACADEMIES.

se Morgan Studios,
150 WEST 87TH ST.
East of Carnegie Hall, Instruction in
Parisian Dances, Tel., 840—Col.

DERN DANCES
Haitem, Boston, Tango, Mexico,
Private Lessons, 1 to 10 P. M.
104 West 75th St.
Columbus.

TON, COLLEGES, SCHOOLS.
Makeup, Sportland, Penmanship,
Service and Stenotype Departments,
Day & Night Sessions.
Call or write to—
1234 Street and Lenox Avenue.
German lessons given at your own
time; terms very low. Write B.

NS WANTED—FEMALES.
Colleges, Schools, etc.—200.
Daily and Sunday.
LADIES—Become diamond jewelry experts; special
positions with jewelers; pay \$25-\$75 weekly;
free catalogue. Jewelers' Art School, 110 West
40th St.

COOKS, ETC.
Cook wishes position, by day or
evening, M. Ziegler, care of Lebowitz,
Hungarian, formerly landed wishes
German woman, very compe-
tent; reference.
LADIES, wishes position; make all
references; no cards. 628 East
107th St.

Capable to
wants position;
German; can
STRATED, A. C.
CONSIDER
MAKES SALARY
MAN; OUTS
GANIZER, AN
CAPACITY, I
QUALITY IN

PERIENCE; FORMER EMPLOY-
ERS STATE, "EXCELLENT STE-
ADY, COMMON SENSE." A. X.
140 HENRIAD.
STENOGRAPHER—Refined young lady, 19, high
school graduate; three years' experience, two
years' teaching; fluent English; with official count-
ing certificate; competent and trustworthy. K.

STENOGRAPHER, typewriter office work
Blanch American girl, age 20; experienced, re-
ference. Phone, 1477—Cypress.
STENOGRAPHER, capable German, English dis-
tinction, excellent, copying, desirable home work;
moderate. Miss Samson, 170 Madison Ave., 8th av.

STENOGRAPHER, two years' experience, neat
writing, competent, \$9. \$10. W. W. 161 Herald
Downtown.
STENOGRAPHER, office assistant, refined young
lady, four years' experience; references; \$12.
Amboy, 407 Herald Downtown.

UNDERGRADUATE would care for invalid ill-
or weak child; refined, reference, C. W. 320
Berfield.
VISITING governess—French language taught by
Parisian; visiting or home. Phantiques, 66 West
107th.

HOUSEKEEPERS and Janitresses.
HOUSEKEEPER—Wanted, position as house-
keeper by educated German lady, about 40;
references. G. E. 142 Ascension St., Passaic,
N. J.

HOUSEKEEPER—A middle aged woman desires
position as housekeeper for elderly couple, 124
East 44th.
HELP WANTED—FEMALES.
Bill clerk or typewriter; must have at least two
years' experience; wages \$12. Apply to B.H.,
P. O. box 1721.

BOOKKEEPER—Wanted, competent bookkeeper,
knowledge of import business; able
to take dictation; keep books, make invoices;
state salary wanted and give references. M. L.,
180 Herald.

DRAPERS AND PINNERS
EXPERIENCED, ON LA-
DIES' DRESSES, R. B. ROTH-
FIELD, 112 MADISON AV.,
CORNER 30TH ST.

HOUSEWORK—Experienced girl
for general housework; best reference required.
LADIES—Become diamond jewelry experts; special
positions with jewelers; pay \$25-\$75 weekly;
free catalogue. Jewelers' Art School, 110 West
40th St.

LADIES artistically inclined to work for us
in their homes. Apply by letter only. Kalos
Mfr. Co., 43 West 27th St.

LORD & TAYLOR
regulate
EXPERIENCED MILLINERS
AND IMPROVERS.

Capable to
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FIELD, 112 MADISON AV.,
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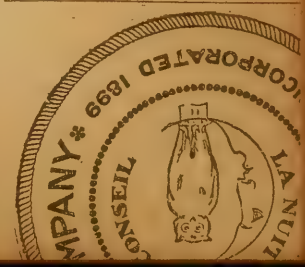
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Mfr. Co., 43 West 27th St.

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EXPERIENCED MILLINERS
AND IMPROVERS.

Stock No. 16.

Engelmann Spruce --- Colorado.



SATURDAY, FEBRUARY 14, 1914.
ENTRY PAGES.

READERS:—The Herald to-day twenty pages. Our readers that their newsdealers deliver tire paper.



ages for all parts of the world the company's branch office in Building, Herald square.

DAY'S HERALD.

ers and bankers declare that n a rising tide and praise the that showing that a new era is at hand.

chine guns and ammunition the City to protect the em- passes the bill creating six of the navy.

in Colombia stronger than Granting of oil concession to Colombia.

regime to wane throughout the heavy snowstorm follows in that something of that kind might be ex-

is a true business condition of lev and great array of facts prospect editorial is read

what national defence needs and why it is needed. But, then, what can be expected? The members of the Board are merely salt water men, skilled in their craft and filled with unselfish patriotism, and, therefore, why should they count against the logrollers, road builders and pork barrelists who are out for the same old appropriation, less the same old flag? Such being the case, how much better it would be if the President and his Secretary of the Navy, like the General Board, came out flatfooted and asked for what national defence needed, instead of back-ing and filling around what politics—and cheap politics at that—designed to dole out to them?

Any way, a Presidential Good for primary ought to be very THE "INS" useful to a President as against opponents within his own party.

The Severe Blizzard.
 A southwestern storm moving toward the Middle Atlantic coast yesterday inaugurated a genuine blizzard in New York. The storm centre has not yet reached the Atlantic coast line, but it will probably do so early to-day, and the energy of the disturbance will doubtless increase as it comes within the influence of the ocean.

It should be hardly necessary to point out the need of great care in the navigation of all the waters adjacent to New York until the gales subside. It is to be hoped that the snow will not continue beyond to-morrow morning, but the heavy winds may prevail for thirty-six hours in this vicinity.

Members of the House "WOODY" PULS of Representatives are THE STRINGS, advocating a mechanical scheme for voting, just as if they haven't one now.

Light Ahead for Colombia.
 Hope that the United States will ever agree to the retro-creation of the Republic of Panama might create for Mr. Roosevelt's over-

ing to the Herald's correspondent at Bogotá is "fast dividing" in Colombia, according to the Herald's correspondents do not

Another hope that may as well "dwindle" from the Colombian mind is that the United States will ever agree to the retro-

But the abandonment of these hopes never be taken seriously. campaign talk, and campaign talk should

Engelmann Spruce --- Colorado.

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The Difference.
 Solemn note of warning Wilson against the danger his taking a hand in Pennsylvania is sounded by the Philadelphians. The President is only dictated a ticket for democrats, but to make has placed all Pennsylvania at the disposal of the man The fate that overtook as the result of his attack his party in respect to Folger is cited by that temporary. As if that wishes a parallel!

Doesn't the Public League President Arthur and Republican politicians, while President Mitchell Palmer are—well, If all the candidates for Win Powers it would seem of picking out a Controller and Commissioner. Now, should we be for Win Powers? Must we name?

"Progress National GREAT NEED, need of the need of the

Every homely man he like" Abe Lincoln.—Phil- Leader. What chance can Phil- becoming a reserve city, newspapers to indulge in to Secretary of the Treas-

PERSONAL INTE

Herald Weather

[Based on meteorological received by the Herald.] The weather in New York yesterday until late in the morning. But as the day can't fail, and at night set in.

The weather in the Al-

Thousands See Dog With Rabid Go Through Act at Hippodrome

Canine Which Had Been Behaving Queerly Went Part of Grabbing a "Tramp" Until Nature of Ailment Discovered by Veterinarian, Who Chloroformed Him

One of the actors on the payroll of the night and to-day when he was chloroformed was killed with chloroform yesterday because he had rabies, and cold chills ran up and down the spine of Thomas Mullins, the dog's partner in a comedy sketch, so often yesterday that he looked like a victim of stage fright. Twice a day for twenty-four weeks Jack, a white English bull terrier, has pursued Mullins, a tramp, in the farm scene in "America," and swinging to the tramp's coat-tails has growled and shaken them.

The dog had rabies for days before Miss Louise Beaufort, his owner, or Mr. Mullins knew it. The thousands of spectators who watched the Hippodrome spectacle during the Lincoln's birthday matinee were watching a mad dog attack a man, but they didn't know it.

Jack was bitten by a Boston bulldog three weeks ago. Miss Beaufort bathed the wound with antiseptics, but it healed slowly.

"He lost his bark a few days ago and would only whine," she said yesterday. After the matinee I took him to the veterinary hospital of Dr. H. K. Miller, in West Fifty-third street. He kept Jack over-

AMUSEMENTS.

TYSON COMPANY'S ANNOUNCEMENT.

WE RESPECTFULLY ANNOUNCE THAT WE HAVE AN APPLE SPLENDID EXCELLENT SEATS FOR ALL NEW YORK FIRST CLASS THEATRES. ALL SEATS TO THE CONTRARY NOTWITHSTANDING. WE CAN ASSURE OUR PATRONS THAT AT ALL LEADING HOTELS.

WINTER GARDEN.

MATINEE TO-DAY AT 2. GREATST OF THE WHITE. THE WORLD. SHOWS. Sunday Night Concert. Best Bill in Town. Maxine Elliott's Theatre. 230 N. B. A New Play. HELP WAN.

LYRIC.

TO-NIGHT AT 8 SHARE. MADONNE TO-DAY AT 2. WILLIAM FAVERSHAM. ALL STAR CAST IN OTHELLO.

SHUBERT.

THEA. 44th. W. of B. WAY. Eves 8:15. Mat. 2:15. To-day & Wed. 2:15.

mpel
elta
Applause
ung at Metropolitan,
nt Gathering of
y Present.

"data" was sung at the night while snow fell upon the role of chills ran up and down the spine of Thomas Mullins, who-derable brilliancy, in the "Ah, fors, e lui" Mr. Amato was ad-looked like a victim of stage fright. Twice a day for twenty-four weeks Jack, a white English bull terrier, has pursued Mullins, a tramp, in the farm scene in "America," and swinging to the tramp's coat-tails has growled and shaken them.

Francis K. Pendleton
General and Mrs. Lloyd S.
13. Mrs. Bryce was in
Mrs. Pendleton in claret
black lace.
Mrs. Forsyth Wickes, in
e Mr. and Mrs. Richard
Wickes wore velvet in
and light blue, and Mrs.
were velvet.
Mrs. James Aber-
Mrs. Frederic Bronson
James A. Burden.
Mr. and Mrs. George L.
and Mrs. Griswold A.
Mr. and Mrs. Goodhue
Mrs. Snowden Farneslock
were Misses Angelica
and Marjorie A. Curtis.
Mrs. Frederic Pear-
Munroe, Miss Josephine
essrs. A. Muller-Ury and
Mrs. William Lowe Rice
and Mrs. Augustus

Stock No. 17.

Amabilis Fir.

LOOK HI
Broadway,
39th St.
Building,
1,416 Broadway,
Entire Cor. Floor, 7
Apply POTTER & BRO. to
to rent. Call, while or
at very low rent, will do
(to agent, on
METROPOL
TOWNE
22D FLO
TO SUBLET IN WHOL
VALERIDGE S. VALL
46TH, 226 West—Partly an
ble business; also basement
it.

NEW BUILD
First floor and basement,
CHAMBERLAIN for low
BURN, 68-72 East 13th st.
THREE LOTS, 120X100, for
posess; heat, power, freight
104th.

Above 68th St.—5th Av.
OFFICES, Studios, clearance
and subway; \$10 upward.
1,947 Broadway, 66th.

Borough of B.
8 Modern Lots,
Convenient with all
Sprinkled, ample
Light three sides; clean
About \$5,000-80,000 ft. in
Help Easily on
Convenient to all
Lowest Price
Owner, 570 WILSON ST.

THREE LOTS, 50X100 feet.
factory building; electric
sprinklers, hot Lexington

Borough of
SPLENDID opportunity for
Floor to rent, furnished
use of garage; strictly up
venient location; desire to
terms reasonable. Mrs. J.
av., Flushing, N. Y. Telop

DWELLING HOUSE
A—A—A—Handsome in
room with bath; reasonable
\$150; will sell all or partly
West 44th

DWELLING HOUSE
20TH, 242 West—18 rooms
rooming or boarding house
JOHN P. FLEET, 302 West

23 WEST 3
Four story, brown
to let; size 10
Eleven rooms, all
Rooming
GRIMSHANK COMA
FURNISHING, including a
71ST, 271 West—1,414 ft

123 EAST 12
Borough of

Westchester County—Sale or Rent.
ALL DESIRABLE HOUSES
for sale or rent in Mount Vernon
are listed at the busy corner
Tel., 485
Anderson Realty Co.,
Mount Vernon,
N. Y.

FOR RENT.
Unfurnished and furnished Homes and Batches
in Scarsdale, Hartsdale and White Plains.

ANGELL SCARSDALE, N. Y.
AND CO. OFFICE, STATION PARK
TELEPHONE 300 SCARSDALE
Kenneth Ives & Co.,
Hudson River 7 E. 42d

MOUNT VERNON, N. Y.
the beautiful city of homes; New York's best
residential suburb; 28 minutes from Grand Cen-
tral; we have all desirable property for sale and
rent. Write, call or telephone.

RICH & GILL.
Tel., 1612.
South 3d av.

RYE REAL ESTATE.
Houses and Bungalows for rent. CHARLES S.
FALKENBERG, Office New Haven Railroad sta-
tion; come out or write. Telephone 48-W—Rye.

New York State—Sale or Rent.
125 acre Dutchess county Farm; beautiful prop-
erty for summer home; 12 room Colonial house;
also four room farm Cottage; price \$9,500; no
exchange. JONES, 612 West 112th st.

Connecticut—Sale or Rent.
\$25,000—Successful Boarding House, Walker Val-
ley, Ulster county, N. Y.; about 18 acres; ex-
cellent water, fruit, shade. J. S. BAYON, 14
Morningside av.

At Greenwiche, Conn.
This splendid COUNTRY HOME has just
been completed and is within 800 feet from the
Ledgebrook Club
The appointments are the very best and
most unique but practical features are appar-
ent everywhere.
The Living Room is distinctive attractive
and unusual in design—refined roads,
Electricity, city water, etc.; modernly equipped
Garage.
A VERY COMPLETE PLACE.
PILOTS & HOUSE WILL BE SOLD AT
A. O. LAMON, 17 Madison av., N. Y.

1 1/2 to 5 Acre Building Plots
Exceptionally Well Constructed House
and this
Belle Haven, GREENWICH, CONN.—FIR-
MIST HOUSES to rent, one with nine bedrooms,
the other with three bedrooms,
each bedroom, garage, for season of 1914, at
\$2,000 and \$1,800 respectively; most beautiful
suburb within commuting distance. Booklet and
information on request. Box 112, Green-
wich, Baites, Farms, BISHOP & ROCK.

New Jersey—Sale or Rent.
AYON BY THE SEA.
Choice plot 100X225, on East End av., for
salt, facing Spruce Lagoon, 1,000 feet from
neighborhood. Apply to EUGENE C. PIERSON,
141 Broadway, New York.

AT Mountain Station, South Orange, a 10 and 13
room House, all improvements, \$500 and \$10 per
month. O. C. THOMPSON, 207 Elm st., New



Westchester County—Sale or Rent.
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Manhattan.
Plumbing & Heating Co. against
Floorfoot Tenement Co. owner.
218 & 220 W. James Curran Mfg
Co. lessee & contractor.
Meyer, contractor.
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White Spruce.

Grinder Run No. 190.

Western Hemlock.

Grinder Run No. 9.

Sitka Spruce.

Grinder Run No. 6.

Lodgepole Pine. --- Montana..

Grinder Run No. 14.

Western Yellow Pine.

Grinder Run No. 8.

Balsam Fir.

Grinder Run No. 27.

Lodgepole Pine --- California.

Grinder Run No. 1.

Red Fir.

Grinder Run No. 2.

Hemlock.

Grinder Run No. 61.

Tamarack.

Grinder Run No. 27.

Noble Fir.

Grinder Run No. 11.

Alpine Fir.

Grinder Run No. 12.

White Fir.

Grinder Run No. 24.

Engelmann Spruce --- Colorado.

Grinder Run No. 14.

Amabilis Fir.

Grinder Run No. 10.

Jack Pine.

Grinder Run No. 30.

White Pine.

Grinder Run No. 11.

Aspen.

Grinder Run No. 3.

Birch.

Grinder Run No. 5.

Black Gum.

Grinder Run No. 10.

Loblolly Pine --- fall cut.

Grinder Run No. 19.

Lowland Fir.

Grinder Run No. 2.



Western Larch.

Grinder Run No. 1.

UNITED STATES DEPARTMENT OF AGRICULTURE



BULLETIN No. 344

Contribution from the Bureau of Entomology
L. O. HOWARD, Chief.



Washington, D. C.

PROFESSIONAL PAPER.

January 18, 1916

STUDIES ON THE BIOLOGY OF THE ARIZONA WILD
COTTON WEEVIL.¹

By B. R. COAD,

Entomological Assistant, Southern Field Crop Insect Investigations.

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INTRODUCTION.

Early in 1913 it was announced by Mr. O. F. Cook of the Department of Agriculture that a weevil, apparently identical with the Mexican cotton boll weevil (*Anthonomus grandis* Boh.), had been found breeding in the fruit of a wild cotton plant (*Thurberia thespoides*) in the mountains of southeastern Arizona.² This announcement was at once followed by explorations in Arizona to determine the distribution of the weevil and its host plant, and research work on the habits, life history, and economic importance of the species. Specimens were sent to the writer at Victoria, Tex., during the summer of 1913, and there as many as possible of their life functions were tested in comparison with the native weevils. Taxonomic study of the Texas and Arizona weevils showed the latter to be a distinct variety, and it was described by Mr. W. Dwight Pierce as *Anthonomus grandis thurberiae*.³ The biological investigations showed

¹ *Anthonomus grandis thurberiae* Pierce.

² Cook, O. F. A wild host plant of the boll weevil in Arizona. *In Science*, n. s., v. 27, no. 946, p. 259-261, Feb., 1913.

³ Pierce, W. D. The occurrence of a cotton boll weevil in Arizona. *In U. S. Dept. Agr., Jour. Agr. Research*, v. 1, no. 2, p. 89-96, Nov. 10, 1913.

NOTE.—The investigations on which this paper is based were conducted under the direction of W. D. Hunter, in charge of Southern Field Crop Insect Investigations.

the two forms to interbreed very readily, however, thus demonstrating their very close relationship.

The biology of this weevil as studied at Victoria has been discussed in two papers.¹

In the spring of 1914 the writer was stationed near Tucson, Ariz., where he studied the Thurberia weevil and its host plant under their natural conditions. These studies consisted of biological investigations similar to those conducted in Texas as well as the consideration of the possible and probable economic importance of the weevil in the arid West. The economic phases of the problem have been dealt with in another report,² so they will be only very briefly mentioned in the present paper.

The principal object of this report is to afford a comparison of the life functions of the weevils as performed by: (1) Texas cotton weevils at Victoria, Tex.; (2) Arizona Thurberia weevils at Victoria, Tex.; and (3) Arizona Thurberia weevils in Arizona. The first two subjects have already been covered in the papers previously mentioned and the last is discussed in the present paper. By a proper consideration of the activity and adaptability of the different forms of weevils under the same environmental conditions and of the same form of weevil under the different conditions it is possible to determine much of importance concerning the exact relation of the two varieties and the extent of variation and adaptation to be expected from each.

For the Arizona studies a camp was established at the Agua Caliente Ranch, about 18 miles east of Tucson. This ranch is located in the foothills of the Santa Catalina Mountains, near the eastern end of the range, at about 2,800 feet elevation. The various breeding experiments described were conducted in this tent while the field tests were located on the near-by irrigated land. These studies were continued from April 16, 1914, to November 16, 1914.

DISTRIBUTION OF THE THURBERIA PLANT AND WEEVIL.

The weevil is not known to occur on any plant other than Thurberia in Arizona, and it seems so closely linked with this plant that every Thurberia plant may be considered as a potential host for the species even though all of these plants do not harbor weevils now. Consequently knowledge of the distribution of the plant is of great importance in the study of the weevil.

The distribution of the Thurberia plant is but imperfectly known at present. Explorations have been made in Arizona by Mr. Vernon Bailey, Prof. J. J. Thornber, Mr. O. F. Cook, Dr. A. W. Morrill, Mr.

¹ Coad, B. R., and Pierce, W. D. Studies of the Arizona Thurberia weevil on cotton in Texas. *In Proc. Ent. Soc. Wash.*, v. 16, no. 1, p. 23-27, Mar., 1914.

Coad, B. R. Recent studies of the Mexican Cotton Boll Weevil. *U. S. Dept. Agr., Bul. 231*, 34p., Aug. 2, 1915.

² Coad, B. R. Relation of the Arizona Wild Cotton Weevil to Cotton Planting in the Arid West. *U. S. Dept. Agr., Bul. 233*, 12 p., 4 pl., May 27, 1915.

W. Dwight Pierce, Mr. E. A. Schwarz, and Mr. H. S. Barber, but the only data we have concerning the occurrence of the plant in Mexico are the records found with the specimens in the various herbaria.

The various explorations in Arizona have shown the plant to be present in the following localities: Santa Catalina, Santa Rita, Tanque Verde, Rincon, Mule Pass, Huachuca, Chiricahua, Superstition, Bradshaw, Dos Cabezos, and Dragoon Mountains, Globe, and Fish Canyon of the Salt River Valley. (Fig. 1.) So far the plant has not been located in any of the mountain ranges west of Tucson, but explorations have been conducted in only two or three of these and it is quite possible that it occurs there.

The writer is indebted to Mr. F. L. Lewton, of the Division of Textiles, United States National Museum, for a copy of the data on the specimens of this plant in the following herbaria: Gray Herbarium of Harvard University; Herbarium of the New York Botanic Garden; Columbian Herbarium, New York Botanic Garden; Herbarium of the Academy of Natural Sciences of Philadelphia; and the United States National Herbarium.

Many of the locality names noted on these are now obsolete and are very difficult to locate, but a general idea of the Mexican distribution of the plant may be secured. Fronteras, Oputo, Tunicachi, and Babusac, all in the State of Sonora, seem to indicate that the plant extends along the mountain ranges in the eastern part of this State and connects with the various localities noted in southwestern Chihuahua. From this point it seems to follow the ranges down at least as far as a point near Guadalajara, Jalisco, Mexico. This is the most southern record the writer has been able to discover.

So far the weevil has been found only in the Santa Catalina, Rincon, Santa Rita, Tanque Verde, and Dos Cabezos Mountains. Of these ranges the first four adjoin the Santa Cruz Valley, in which Tucson is located, and the last is near Bowie. In the examination of the plants found in the other ranges of the State, no signs of weevils were found but the distribution is certainly more general than that now known. Further explorations will probably demonstrate the presence of the weevils in other mountain ranges, at least in the southeastern part of the State.

We have no information concerning the presence of the weevil on *Thurberia* in Mexico, but the writer believes that it will be found extending all along the mountain chain through eastern Sonora, western and southwestern Chihuahua, and then probably connecting directly with the central Mexican territory in which the weevils live on cotton.

HABITAT OF PLANT AND WEEVIL.

The studies of the past season were confined to the mountains around Tucson and the most thoroughly worked of these was the Santa Catalina Range, where the local distribution of the plant and

along the southern and southwestern slopes from the divide at the eastern end to the western tip of the range, practically circled the range. From the western tip of the range trips were made around the western end into the northwestern slopes at Montrose and Romero



FIG. 1.—DISPERSION OF THE WILD COTTON WEEVIL.

Typical location of *Thurberia* plant, below rock, in Agua Caliente Arroyo, Ariz., about $1\frac{1}{2}$ miles from the mouth of the canyon. (Author's illustration.)



FIG. 2.—THE WILD COTTON WEEVIL AND ITS HOST PLANT IN THE LOWER RANGES.

Habitat of *Thurberia thespesioides* and the wild cotton weevil in the lower ranges. This view was taken in the Agua Caliente Arroyo, Ariz., about 100 yards below the plant shown in figure 1. (Author's illustration.)

THURBERIA THESPESIOIDES, THE FOOD PLANT OF THE ARIZONA WILD COTTON WEEVIL, ANTHONOMUS GRANDIS VAR. THURBERIÆ.

Canyons and nearly to Oracle. The writer then crossed the range by the trail above Agua Caliente Canyon, descended into the San Pedro Valley on the northeastern side, and explored the slopes. Combined with these observations numerous trips back and forth throughout the range were made at various points which gave comparatively thorough data on the internal conditions of the mountains.

Thurberia plants were found at intervals throughout this territory. Summarizing these observations it seems impossible to name any certain type of situation as the normal habitat of the Thurberia plant, since it is found in moist canyon beds, in dry arroyos, on dry slopes, and on the top of peaks. However, by far the greater number of plants are located in canyon beds, mountain washes, or arroyos out through the mesa, and in searching a new locality these are usually the most frequent situations in which the plant is found. Thurberia plants growing under these conditions usually develop a more healthy growth than those on the more exposed slopes, and usually the plants at higher altitudes, on slopes and peaks, are found more or less grouped in colonies. Travel for miles through such territory may not disclose a single plant when suddenly colonies of from three plants to several dozens are found. The distribution in canyon beds and washes, however, is quite different, for here the plants are usually found more or less scattered and growing singly, although in many canyons a plant will be found every few yards for several miles. (Pl. I, figs. 1, 2.) Occasionally, in locations particularly well sheltered from the force of the current, a large colony of plants may be found, but such cases are infrequent.

At lower altitudes, on the mesa and plains, Thurberia plants were found extending along the dry arroyos often to a distance of several miles from the base of the mountains. Here, while fairly common, they are scattered, being found along the margin of the channel, on small islands, or in protected situations behind rocks.

The occurrence of the Thurberia plant at an elevation of 7,000 feet was not noted until late in the season, at which time a few were found on a peak at about this elevation, behind Soldiers Canyon. It is interesting to note that one specimen in the Gray Herbarium and another in the Herbarium of the Academy of Sciences of Philadelphia, both collected by Edw. Palmer, bear the following data: "The Frailes above Batatopas, S. W. Chihuahua, Mexico, 7000 feet alt. October."

Back in the interior of the Santa Catalina range in the small canyons draining this country the plants were found to be quite common along the stream beds.

The Arizona wild-cotton weevil was found to be as widely distributed throughout this range as was the Thurberia plant, but the weevils were by no means present on all plants. While the weevils

were found in all types of situations at altitudes from about 2,750 feet to 7,000 feet, they were more abundant on plants growing at elevations of from 3,500 to 5,000 feet. The writer has been unable to determine any type of location as being especially favorable to the maintenance of the weevils.

In the Santa Rita Range the writer confined his studies almost entirely to points of less than 4,000 feet elevation. The country examined was that which lies along the base of the mountains commencing at a point below Madero Canyon and extending nearly to the northern end of the Santa Rita Range. Throughout most of this country the *Thurberia* plant was found extending down the arroyo nearly to the 3,000-foot level, and weevils were located on many of these plants at this elevation.

Very little exploring was done in the Tanque Verde Mountains, but a few trips were made on the northwestern slope above the village of Tanque Verde, where a few plants, some bearing weevils, were located in the "washes" of this comparatively regular slope.

In the Rincons the investigation was limited to the examination from the southern end of the range of some of the lower arroyos which form the headwaters of the Pantano, and *Thurberia* plants and a few weevils were found. Messrs. Barber and Schwarz found plants and weevils on the Manning trail above Mills ranch and Prof. Thorner reported a colony from a short distance above the Shaw ranch.

Investigation seems to have established that the *Thurberia* plant does not occur in the Tucson Range, as this range was explored by Dr. A. W. Morrill and Mr. W. Dwight Pierce during the summer of 1913 with negative results, and a search made by the writer in September, 1914, also proved negative. This range seems far too dry for the existence of the *Thurberia* plant.

SEASONAL ACTIVITY OF PLANT AND WEEVIL IN NATURE.

As the activity of the Arizona wild-cotton weevil in nature is largely dependent upon the growing and fruiting period of the plant, close observations were made, particularly in relation to the time of fruiting. These observations showed the time to vary greatly with the location of the plant, and the most important factor seems to be altitude and its accompanying conditions. The plants observed closely during this season ranged from 2,700 to 5,000 feet, and while no definite lines can be drawn, the following discussion gives the variations in time as they were noted at the different elevations.

Plants growing in the channels of Milagroso, Agua Caliente, and Soldiers Canyon and in the arroyos below these canyons (elevation below 3,000 feet) were all leafed out and squaring heavily by the 1st of May. They began blooming about May 7. After two or three weeks of flowering the buds ceased to appear and there was a

quiet period during which the bolls ripened, opened, and shed their seeds. Then another crop of buds appeared and the same course was repeated. In this manner as many as four crops of fruit were produced by some of these lower plants and many produced three.

Higher in the canyon channels and on the lower slopes (elevation 3,000 to 4,000 feet) the plants started to square shortly after the 1st of June and produced two or three crops before the end of the season. They all began leafing out about the same time as the lower plants just discussed.

About the 1st of July the plants growing at about 4,500 feet started squaring while those above 5,000 feet did not start until July 30 or later, and produced only one crop.

From this is seen the extreme variation in the fruiting period of the plant. This grouping by altitude is of course only approximate because the conditions (moisture, exposure, etc.) vary greatly at the same altitude in different locations.

The active period of the plant will probably vary with the different years according to climatic conditions. The winter of 1913-14 was exceptionally mild and consequently some of the lower plants may have started blooming earlier this season than is usual.

Regardless of the previous activity of the plants, the last crop of fruit (produced during August and September) is always the largest and blooming extends over a longer period at this time. Most of the plants stopped blooming during the latter part of September though quite a few continued blooming into early October.

The appearance of the weevils from hibernation is very scattering during the early spring months. The first record of emergence during the spring of 1914 was an individual noted in a branch of Agua Caliente Canyon at about 3,000 feet altitude on May 10. Following this a few were found active here and there in the mountains, but they were not common until later in the season.

These early individuals fed upon the squares and bolls present, and produced a few progeny in the latter. The resulting weevils emerged after a normal developmental period and aided in the infestation of the large crop of fruit in August and September.

The general emergence of the weevils began shortly after the first of July and by the middle of August nearly all weevils had emerged. These were all quite active on the plants after this time. During the past season the writer did not note a single weevil breeding in the buds of *Thurberia*, although considerable feeding upon them was observed. This is directly contrary to the conditions found by Mr. Pierce in August, 1913, when he observed the weevils breeding abundantly in *Thurberia* buds in both the Santa Catalina and Santa Rita Ranges. This discrepancy in records may be due to some differences in the seasonal conditions.

With the existing variations in time of emergence it is impossible to determine the exact number of generations per year, but most of the weevils seem to have only one or two, the last remaining in the pupal cells in the bolls and so hibernating.

The activity of the weevils seems to continue until stopped by the cold weather. It was greatly decreased in most places through October, but a few weevils were still active on the 1st of November.

EMERGENCE OF WEEVILS.

The study of the weevil activity in nature was greatly confused by the extreme variation in the time of emergence from hibernation. These weevils pass the winter in pupal cells in the *Thurberia* boll and, instead of emerging in the spring with the first warm weather, prolong the dormant period far into the season before leaving the cell. In fact, some individuals have been found in old cells as late as the 1st of September, though nearly all emerge during July and August. Because of the possible economic importance of this delayed emergence in relation to the transfer of the weevil from *Thurberia* to cotton, cage tests were conducted and careful observations made in the field to determine under what conditions the weevils will emerge.

For the cage tests a number of infested *Thurberia* bolls which had remained hanging on the plants since the fall of 1913 were collected in the upper part of Soldiers Canyon on June 6 and were kept in a dry box until the time of starting the tests.

The treatment of the different lots of infested bolls was as follows:

- No. 1. Bolls not moistened placed in empty tumbler in shade.
- No. 2. Bolls not moistened placed in empty tumbler in sun.
- No. 3. Bolls not moistened placed on moist sand in shade.
- No. 4. Bolls not moistened placed on moist sand in sun.
- No. 5. Bolls immersed in water $1\frac{1}{2}$ minutes and placed on moist sand in shade.
- No. 6. Bolls immersed in water $1\frac{1}{2}$ minutes and placed in empty tumbler in shade.
- No. 7. Bolls immersed in water 30 minutes and placed on moist sand in shade.
- No. 8. Bolls immersed in water 30 minutes and placed in dry tumbler in shade.
- No. 9. Bolls immersed in water 30 minutes and placed on moist sand in sun.

These tests were started July 11, and each lot was examined at frequent intervals until September 22 and all emergence noted. Five bolls were placed in each lot. On September 22 all bolls were opened and the condition of the weevils inhabiting them noted.

From the unmoistened bolls placed in dry tumblers no weevils emerged. When the unmoistened bolls were placed on moist sand and left in the shade, two weevils emerged, but when they were placed in the sun none emerged. When the bolls were immersed in water for $1\frac{1}{2}$ minutes and then placed on moist sand in the shade four emerged, but those moistened in the same manner and placed in a dry tumbler in the shade produced none. When immersed in water 30 minutes and left on moist sand in the tent three emerged and those moistened in the same manner and placed on moist sand

in the sun produced none. Those immersed 30 minutes and placed in a dry tumbler in the shade produced one weevil.

These results indicate the importance of moisture in the emergence of the weevils. Mere placing on moist sand caused some weevils to emerge in 5 days, but the bolls moistened and then placed on moist sand in the shade produced the maximum emergence. In the various lots which were placed in the sun not a single weevil emerged regardless of treatment. This was evidently due to the extreme heat in the tumbler. All weevils were found dead in these cells upon examination while many of those in the shade were still alive in the cells.

These experimental tests of the factors producing emergence are far from conclusive, but by combining them with various observations made in the field a fairly definite idea of conditions under which the weevils will emerge may be secured, and by studying the seasonal climatology of the region inhabited by the weevils it is possible to know when to expect the emergence.

The emergence of the weevil shows a very decided relation to the structure of the *Thurberia* boll and is the result of a gradual preparation of the boll which extends over a considerable period of time. In the fall the weevil cell is surrounded by the compact seeds and these in turn are inclosed in the covering of the boll. These soon dry and harden so that emergence is impossible. Then follows a slow changing of the boll extending through the winter months. The seeds around the cell ripen, harden, and separate slightly. The outer covering of the boll cracks apart at the apex and gradually splits toward the base. While this is largely a process of ripening and dessication, it is undoubtedly aided by the occasional rains during the winter and early spring. By spring the boll reaches a condition such that it is easily opened and the seeds scattered by a light crushing, but now the weevil cell itself holds the contents intact. In fact most of the uninfested bolls have opened wide by this time and the seeds have been blown and shaken out by the wind.

At this period it seems usually necessary for the boll to be at least slightly moistened to soften the cell before the weevil can emerge. The tests of the amount of moisture required to accomplish this show that it is variable and that very little is necessary in some cases.

That moistening is not always necessary to allow emergence is shown by the fact that the writer has observed weevils both in the field and in the laboratory emerging from perfectly dry bolls which had not been moistened for weeks. These cases seem to be due to the imperfect formation of the cell, which is weak enough to be broken by the drying of the boll and separation of the seeds.

From these observations concerning the importance of moisture in the emergence of the weevils, it seems quite probable that in the

vicinity of Tucson the normal emergence in the mountains is scattering during the spring and summer months, depending largely upon the frequency of the showers during this period, and that the general emergence is produced by the rains of July and August.

RELATIVE ATTRACTION OF COTTON AND THURBERIA FOR WEEVILS.

During the season a number of tests were made to determine the relative powers of cotton and Thurberia for attracting the weevils. Various types of weevils and different foods were used in the different lots but the method of procedure was identical for all.

Large, weevil-proof screen cages were used. They were placed on bare ground which was kept slightly moist by an irrigation ditch on each side of the row of cages.

In preparing the cage for the test the Thurberia plant was placed upright in one corner about a foot from the wall of the cage and the cotton plant was placed diagonally opposite. Then the weevils were released on the ground in the center of the cage. Following this, examinations were made frequently to determine the amount of feeding on each plant and the weevils present on each. All weevils found on plants were removed and released in the center of the cage. Fresh plants were placed in the cages almost every day or often enough to keep green food present at all times. In order to eliminate the influence of light from any selection the weevils might make, the positions of the plants were reversed daily.

All weevils were hibernated individuals which were removed from their 1913 pupal cells in Thurberia bolls. The observations may best be divided according to the food of the weevils before these were placed in the test cages.

WEEVILS NOT FED BEFORE TESTING.

On the 1st of August 14 males and 14 females removed from bolls collected in December, 1913, in the Santa Rita Mountains were placed immediately in a cage with cotton and Thurberia plants bearing neither squares nor bolls. On August 24 plants with squares and bolls were started and continued as the food for the remainder of the experiment.

Feeding began immediately on both plants and was continued more or less constantly until the close of the experiment on September 17. For the first 15 days the feeding was mostly on Thurberia, but after that time cotton was more or less favored. The summary of the observations for the entire period is as follows:

Cotton attacked.....	records..	24
Thurberia attacked	do.....	16
Weevils on cotton, 3 male, 21 female.....	total..	24
Weevils on Thurberia: 3 male, 14 female, 2 of sex not determined.....	total..	19

From this it is seen that more weevils were observed on cotton and there was also more feeding on this plant than on *Thurberia* in the course of the entire experiment. At the very beginning what seemed to be a preference in favor of *Thurberia* was noted, but this disappeared later.

On the 4th of August 13 females and 12 males were removed from cells in *Thurberia* bolls collected in the Santa Rita Mountains in December, 1913, and kept almost entirely without food (cotton leaves fed only once) until August 7. They were then placed in a cage with *Thurberia* and cotton plants, both bearing buds and bolls. The experiment was continued until September 17 though the last feeding was noted September 11. Throughout this time a slight preference in favor of *Thurberia* was maintained and the summary of observations is as follows:

Cotton attacked.....	records..	7
<i>Thurberia</i> attacked.....	do....	13
Weevils on cotton, 3 male, 4 female, 1 of sex not determined..	total..	8
Weevils on <i>Thurberia</i> : 7 male, 11 female, 1 of sex not determined.....	total..	19

These two tests of unfed weevils total as follows:

	Records.
Cotton attacked.....	31
<i>Thurberia</i> attacked.....	32
Weevils on cotton.....	32
Weevils on <i>Thurberia</i>	38

From these figures it is quite evidently useless to attempt to credit the weevils with a choice for either plant when unfed before testing.

WEEVILS FED UPON COTTON SQUARES BEFORE TESTING.

On the 24th of August 12 weevils of each sex were removed from the hibernation cells in *Thurberia* bolls collected in the Santa Rita Mountains December 4, 1913. These were fed upon cotton squares from this date until August 31 and then placed in a cage with cotton and *Thurberia* plants bearing buds and bolls. This test was continued until September 27 and the feeding continued until that date.

For the first few days a slight preference in favor of cotton was shown, but this soon disappeared and the feeding was much the same on the two plants for the remainder of the experimental period. The summary of observations is as follows:

Attacking cotton.....	records..	9
Attacking <i>Thurberia</i>	do....	7
Weevils on cotton: 8 male, 6 female, 1 sex not determined..	total..	15
Weevils on <i>Thurberia</i> : 11 male, 6 female, 1 sex not determined..	do....	18

From this feeding it is evident that, while the feeding upon cotton squares for the first few days after emergence may have caused a slight preference in favor of cotton plants early in the test, this did not last more than a very short time and then no preference was shown.

WEEVILS FED UPON THURBERIA BEFORE TESTING.

On August 24 another lot of weevils (11 males and 12 females) were removed from cells in *Thurberia* bolls collected in the Santa Rita Mountains December 4, 1913. These weevils were fed upon *Thurberia* buds and leaves until August 31 and then were placed in a cage with *Thurberia* and cotton plants, both bearing squares and bolls. Here the initial feeding showed a preference for *Thurberia*, but this was lost within a few days and the feeding became almost equal on the two plants. The test was continued until September 17 and feeding lasted until that time. The summary of observations for this lot is as follows:

Attacking cotton.....	records..	7
Attacking <i>Thurberia</i>	do....	6
Weevils on cotton: 5 male, 7 female.....	total..	12
Weevils on <i>Thurberia</i> : 7 male, 11 female.....	do....	18

SUMMARY OF ALL TESTS.

The summary of the results of the various experiments just detailed is given in Table I.

TABLE I.—*Relative attraction of cotton and Thurberia for weevils.*

Food before starting test.	Cotton.					Thurberia.				
	Plants attacked.	Weevils.				Plants attacked.	Weevils.			
		Male.	Fe-male.	Sex not determined.	Total.		Male.	Fe-male.	Sex not determined.	Total.
None.....	31	6	25	1	32	32	10	25	3	38
Cotton squares.....	9	8	6	1	15	7	11	6	1	18
<i>Thurberia</i> buds.....	7	5	7	.....	12	6	7	11	.....	18
Total.....	47	19	38	2	59	45	28	42	4	74

From this table it is seen that, while the cotton plants were attacked slightly more than the *Thurberia*, more weevils were observed on the latter. It is interesting to note that in the total of the observations of the weevils on both plants males were noted 47 times and females 80 times. As the weevils used were very nearly equally divided as to sex (49 males and 51 females), this seems an instance of the greater activity of the females.

These cage tests seem to indicate that unfed hibernated *Thurberia* weevils display no preference for either plant, while those fed on either plant exclusively for a few days after emergence will at first favor that plant slightly when offered a choice, but will soon feed equally on both. From this it would seem that neither plant has the power to attract the weevils away from the other, but later observations made in the field are rather contradictory to this. The field cotton at the ranch this season was repeatedly attacked by the weevils, and, while there was considerable injury to the squares and bolls on this cotton, only two bolls were attacked on

several *Thurberia* plants growing so close that some branches overlapped the cotton.

LIFE-HISTORY STUDIES.

FECUNDITY.

A number of series of *Thurberia* weevils were tested to determine the fecundity of the females on the different foods.

WEEVILS FED ON COTTON SQUARES.

During the season 14 pairs of weevils were mated on cotton squares in glass tumblers and the fecundity determined. These weevils either emerged from or were removed from their hibernation cells in *Thurberia* bolls collected at different points in the Santa Catalina and Santa Rita Mountains. They were all hibernated individuals. Nearly all were left on cotton squares until the close of the experiment, but two were removed from this food after 17 days and fed on cotton bolls for the remainder of the period.

Of the 14 females thus mated, 13 oviposited more or less normally. The other one, placed with cotton squares August 31, deposited one egg October 5 and another one October 7 and then stopped. This female was still alive and feeding at the close of the experiment on November 8. The data showing the activities of the 13 normal females are given in Table II.

Owing to the shorter active season to which the Arizona weevils are accustomed, it seemed quite probable that the average fecundity of the females would not equal that of the Texas weevils, but this is seen not to be the case. These averages secured with *thurberiae* on cotton squares in 1914 are very nearly as high as those from the best series of *grandis* reared in Texas on the same food in 1913, and they are higher than the general average of all series of *grandis*.

TABLE II.—Fecundity of *Anthonomus grandis thurberiae* mated on cotton squares, Agua Caliente ranch, Arizona, 1914.

Source of weevils.	Date first fed squares.	Date first egg.	Period fed squares to deposition.	Date last eggs.	Oviposition period.	Total eggs.	Average eggs per day.	Date female dead.	Date male dead.
Emerged from cells in <i>Thurberia</i> bolls.....	June 23	July 5	Days. 13	Aug. 10	36	176	4.9	Aug. 10	
Removed from cells in <i>Thurberia</i> bolls.....	June 25	July 15	20	Aug. 7	24	116	4.8	Aug. 7	
Do.....	July 8	July 12	4	Aug. 31	51	82	1.6	Sept. 14	July 12
Do.....	do.....	July 13	5	Aug. 14	33	150	4.5	Aug. 11	Sept. 11
Do.....	do.....	July 15	7	Aug. 19	36	126	3.5	Aug. 24	Aug. 14
Do.....	July 11	do.....	4	Aug. 28	45	217	4.8	Aug. 30	Sept. 4
Do.....	do.....	do.....	4	Aug. 13	30	144	4.8	Aug. 14	Sept. 11
Do.....	Aug. 11	Aug. 21	10	Sept. 16	27	92	3.4	Sept. 19	
Do.....	do.....	Aug. 20	9	Oct. 31	72	309	4.3	.....	
Do.....	do.....	Sept. 1	20	Nov. 2	62	299	4.8	.....	
Do.....	Aug. 31	Sept. 12	12	Nov. 4	54	156	2.9	.....	Oct. 31
Do. ¹	do.....	Sept. 7	7	do.....	59	39	.7	.....	Sept. 12
Do. ¹	do.....	Sept. 12	12	Oct. 19	38	141	3.7	Oct. 19	
Total.....			127		567	2,047			
Average.....			9.7		43.6	157.4	3.4		
Maximum.....			20		72	309	4.9		
Minimum.....			4		24	39	.7		

¹ These weevils were fed on squares until Sept. 17, and then on bolls.

The transfer of some of the weevils from cotton squares to cotton bolls late in life seemed to have no effect upon their oviposition as they continued ovipositing at about the same rate without a break.

It is interesting to compare the data presented in this table with the results secured by mating *thurberiae* on cotton squares in the same manner at Victoria, Tex., in 1913. Table III gives this comparison.

TABLE III.—Comparison of results secured in Arizona and Texas with regard to fecundity of *Anthonomus grandis thurberiae*.

	Average oviposition period.	Average eggs per female.	Average eggs per female. per day.	Maximum eggs per female.
	<i>Days.</i>			
Texas.....	32	103.0	3.2	173
Arizona.....	45.1	157.4	3.4	309

This table shows the greater fecundity of the variety under Arizona conditions than under the unnatural environment of southern Texas, although the daily rate of oviposition was much the same.

WEEVILS FED ON COTTON BOLLS.

Four pairs of hibernated *thurberiae* were removed from the cells in *Thurberia* bolls and mated on cotton bolls in glass tumblers in the same manner that others were mated on cotton squares. The results secured from these are shown in Table IV.

TABLE IV.—Fecundity of *Anthonomus grandis thurberiae* on cotton bolls, *Agua Caliente Ranch, Arizona, 1914.*

Source of weevils.	Date first fed bolls.	Date first egg.	Period fed bolls to deposition.	Date last egg.	Oviposition period.	Total eggs.	Average eggs per day.	Date female dead.	Date male dead.
			<i>Days.</i>		<i>Days.</i>				
Removed from cells in <i>Thurberia</i> bolls.....	July 13	July 20	7	Aug. 13	25	7	0.3	Aug. 24	July 19
Do.....	July 15	July 19	4	Aug. 10	22	64	2.9	Aug. 13	Aug. 17
Do.....	do.	do.	4	Aug. 17	29	84	2.9	Aug. 30	
Do.....	Aug. 11	Aug. 21	10	Oct. 14	55	190	3.4	Oct. 21	
Total.....			25		131	345			
Average.....			6.2		32.7	86.2	2.6		
Maximum.....			10		55	190	3.4		
Minimum.....			4		22	7	.3		

From this table it is seen that the weevils displayed a comparatively low degree of fecundity. This is seemingly in direct contradiction to the results secured in the series of weevils on live plants in the field and also of those offered a choice between cotton squares and bolls. Quite a number of tests in glass tumblers were made during the season to determine the preference displayed by the weevils in

relation to cotton bolls and squares. These all gave the same result, namely, that cotton bolls were much preferred to cotton squares. While there would always be some feeding upon the squares and an occasional egg would be deposited in them, by far the greater part of the feeding and deposition was on the bolls. In the field experiments where the weevils were placed on growing cotton plants there was some feeding on squares but the bolls received almost all of the feeding and deposition. In the breeding experiments where weevils were mated on squares for some time and then placed on bolls the oviposition continued through the change of food without diminution. In view of these observations it seems quite reasonable to believe that the cotton bolls are better suited to the weevil than the squares and hence it is hard to account for the much lower fecundity shown by the weevils in this boll-fed series than by those in the corresponding series fed upon squares.

WEEVILS FED ON THURBERIA.

At different times during the season weevils were removed from their hibernation cells in *Thurberia* bolls and mated in glass tumblers containing *Thurberia* leaves, squares, and bolls. For some reason these attempts to secure egg deposition were almost total failures. Nine pairs were mated in this manner and of these, seven females failed to deposit any eggs, one deposited a single egg, and the other deposited 66 eggs. This last female was placed with the food September 1, deposited the first egg September 23, and the last October 16, giving an oviposition period of 24 days. The average number of eggs per day was 2.7.

Some of the females which did not oviposit were allowed to live until their normal death, while others were killed after some weeks because of lack of food. It is difficult to determine the cause of this failure of the females to oviposit, but it is probably due to some fault in the breeding methods. One point which was noted in this connection was the extreme rapidity with which *Thurberia* bolls ripen after removal from the plant and hence become unfit for egg deposition. The seeds dry and harden very rapidly even though the boll is quite small. In such bolls the weevils will feed through the tender tissue near the stem end, but will not oviposit. The experimental conditions (cages, tumblers, etc.) were exactly the same as those for weevils upon cotton squares and bolls which were ovipositing normally at this same time, so the cause evidently was some fault with the condition of the food. Two females which were allowed to remain in tumblers with *Thurberia* bolls and squares for 14 days without oviposition were then transferred to living *Thurberia* plants in the field and they immediately began ovipositing.

DEVELOPMENTAL PERIOD.

IN COTTON SQUARES.

No observations were made on the length of the different immature stages in cotton squares, but the total developmental period was studied throughout the season from eggs deposited from July 6 to about the 1st of November. The squares were placed on moist sand in glass tumblers each day and the sand was kept damp. The date of the emergence of the adult was noted and the period between egg deposition and adult emergence was thus determined. However, this period was often not a true developmental period because it was found that, instead of emerging within a day or two after transforming to adult, as is the case with *grandis* in the Southern States, many of the weevils would remain in the cells for some days after becoming adult. This was particularly the case during the latter part of the season.

In watching for the emergence of adults each lot of squares was examined daily for about 20 days after egg deposition and then was examined only occasionally. In this way the dates of emergence were secured when the weevils emerged shortly after becoming adults, but late in the season many emerged after the daily observations had been stopped and consequently no figures were secured on their time of emergence. As this delayed emergence did not become usual with the weevils until those from eggs deposited after the 1st of September had developed, the data have been divided at this date and are given in Tables V and VI.

The figures in Table V are probably very nearly those for a developmental period such as is experienced by the Texas cotton boll weevils and the periods are surprisingly similar to those of cotton boll weevils. It is interesting to note that the average developmental period of both sexes of *thurberiae* in Arizona was 15.4 days while in southern Texas it was 18.5 days. It seems probable that nearly all of the weevils included in Table VI delayed emergence. This was probably due to the approach of the time for entering hibernation. From the squares receiving eggs before September 1, 71 weevils emerged in normal time and 2 were retarded, while from those receiving eggs after this date 10 emerged more or less normally and 48 were retarded.

In this series 1,260 squares containing eggs were observed and these produced 145 weevils, including those found in the cells. In other words, only 11.5 per cent of the squares receiving eggs produced adults. This is a very low percentage and seems to indicate that the cotton squares are not completely suited to the development of the Arizona weevil.

TABLE V.—*Developmental period of Anthonomus grandis thurberiae in cotton squares, Arizona, 1914; eggs deposited before Sept. 1.*

Date eggs depos- ited.	Date adults emerged.	Males.			Females.			Adult emerged but date not noted.	Stages found upon examination of squares.
		Period.	Num- ber weevils.	Weevil days. ¹	Period.	Num- ber weevils.	Weevil days. ¹		
		<i>Days.</i>			<i>Days.</i>				
July 6	July 24	18	1	18					
7	July 25	18	1	18	18	1	18		
8	July 22				14	1	14		
9	July 23	14	1	14	14	2	28		
9	July 24	15	1	15					
11	July 25				14	1	14		
11	July 26				15	1	15		
12	July 25	13	2	26					
12	July 28	16	1	16					
13	do.	15	1	15					
14	July 27	13	1	13					
14	July 28				14	1	14		
14	Aug. 1				18	1	18		
15	July 29	14	3	42	14	1	14		1 adult died in cell without emerging.
15	July 30	15	1	15	15	1	15		
15	Aug. 1	17	1	17					
16	July 29	13	1	13					
16	July 30	14	1	14	14	2	28		Do.
16	Aug. 1	16	2	32	16	2	32		
16	Aug. 4	18	2	36					
17	Aug. 1	15	2	30	15	3	45		1 male dead.
18	do.				14	3	42		1 adult dead in cell.
18	Aug. 3				16	1	16		
19	Aug. 2	14	1	14	14	1	14		
19	Aug. 3				15	2	30		
19	Aug. 4				16	1	16		
20	Aug. 3	14	1	14	14	2	28		
23	Aug. 7	15	1	15					
23	Aug. 11				19	1	19		
24	Aug. 8	15	1	15					
24	Aug. 10	17	1	17	17	1	17		
24	Aug. 13	20	1	20					² 1
25	Aug. 7	13	1	13					
25	Aug. 10	16	1	16	16	2	32		
25	Aug. 12				18	1	18		
27								³ 1	
28	Aug. 12	15	1	15					
30	Aug. 17	18	1	18					
Aug. 1	do.	16	1	16					
1	Aug. 18				17	1	17		
2	Aug. 21	19	1	19					
3	Aug. 19	16	1	16					
3	Aug. 20	17	1	17					
11	Aug. 30	19	1	19					
28	Sept. 11	14	1	14					
Total.....			38	592		33	504	2	4.
Average.....				15.6			15.3		
Total weevils of both sexes.				71					
Average period for both sexes.				15.4					

¹ "Weevil days" is the term applied to the sum of the time periods experienced by the various individuals during the course of the observations.

² Female.

³ Male.

At the close of the experiment in November all squares were examined and the following stages were found remaining in them: 9 dead adults, 5 live adults, 7 live pupæ, and 12 live larvæ. The live adults were found only in squares receiving eggs after October 14, so it is quite possible that they would still have emerged. The immature stages were in the later lots of squares and probably had not had time to become adult.

TABLE VI.—*Developmental period of Anthonomus grandis thurberiae in cotton squares, Arizona, 1914; eggs deposited after Sept. 1.*

Date eggs de- posited.	Date adults emerged.	Males.			Females.			Adult emerged but date not noted.	Stages found upon examination of squares.
		Period.	Number weevils.	Weevil days.	Period.	Number weevils.	Weevil days.		
		<i>Days.</i>			<i>Days.</i>				
Sept. 1								1 male.....	
2								1 female.....	
11								2 females.....	
12								3 males and 2 fe- males.....	
16								1 weevil.....	
17	Oct. 3	18	2	36	18	1	18	1 female.....	
19	Oct. 21	32	1	32				2 males and 3 fe- males.....	1 female dead.
21								1 male and 2 fe- males.....	
23								4 males and 1 fe- male.....	
29	Oct. 21	22	2	44	22	2	44	1 male and 2 fe- males.....	
Oct. 1	do.....	20	1	20				3 females.....	
3	Oct. 22	19	1	19				2 males and 4 fe- males.....	2 females and 1 male dead.
5								2 males and 1 fe- male.....	
7								1 male and 1 female	
9								1 weevil.....	
12								2 males and 3 fe- males.....	2 females and 1 male alive.
14								1 female.....	1 female alive.
16								1 male and 1 female	
19									
21								1 teneral male, 4 pupæ, and 1 lar- va alive.....	
23								2 pupæ and 1 larva alive in cells Nov. 9.	
26								1 pupa and 3 larvæ alive in cells Nov. 9.	
28								2 larvæ alive in cells Nov. 9.	
31								3 larvæ alive in cells Nov. 9.	
Nov. 2								2 larvæ alive in cells Nov. 9.	
Total.....			7	151		3	62		
Average.....				21.5			20.6		
Total weevils of both sexes.				10					
Average period, both sexes.				21.3					

In the examination of these squares a great number of the non-producing ones were found to have the contents more or less eaten by weevil larvæ. These larvæ were evidently unable to survive upon this food. Of course the larval mortality is quite high in any breeding series of either *grandis* or *thurberiae* regardless of the food, but this is certainly higher than usual.

IN COTTON BOLLS.

The developmental period of the weevil in cotton bolls was studied in the same manner as that just described for cotton squares. The results of this series are given in Table VII.

TABLE VII.—*Developmental period of Anthonomus grandis thurberiae in cotton bolls, Agua Caliente ranch, Arizona, 1914.*

Date eggs depos- ited.	Date adults emerged.	Males.			Females.			Condition found at examination of bolls at close of experiment on Nov. 10, 1914.
		Period.	Num- ber weevils.	Weevil days.	Period.	Num- ber weevils.	Weevil days.	
July 13	July 30	Days. 17	1	17	Days.			1 live female in cell, 2 dead larvæ.
23								1 live female, 2 pupæ, and 1 larva
24								dead.
25								1 live and 1 dead adult in cells.
27	Aug. 17	21	1	21				1 dead adult in cell.
28								Do.
30								Do. ¹
Aug. 1								Do. ¹
2	Aug. 25	23	1	23				1 male has emerged.
4								1 dead adult in cell. ¹
7	Sept. 4				28	1	28	Do. ¹
13								1 live pupa in cell.
20	Sept. 7				18	1	18	
24								1 dead adult in cell. ¹
28								1 female emerged before Sept. 22.
30								3 dead adults in cells.
31								1 male alive and 1 female dead in
								cells.
Sept. 1	Sept. 22	21	1	21	21	1	21	1 female alive, 2 adults dead.
2								1 male alive in cell.
3								1 male emerged, 1 adult and pupa
								dead.
4								1 male alive in cell.
11								2 adults dead.
12								1 live female.
14								1 male has emerged.
17								1 male, 1 female emerged; 1 male
								alive.
19								2 adults alive, 2 adults dead.
21								3 males emerged, 1 male alive in
								cell.
23								2 males emerged, 3 adults alive in
								cell; 1 male dead in cell.
27								1 male emerged, 1 male and 1 fe-
								male alive in cell, 1 male dead in
								cell.
29								2 males alive in cell.
Oct. 1								1 female emerged, 2 males and 1
								female alive in cell, 1 larva alive
								in cell.
3								1 female emerged, 1 adult dead in
								cell.
5								3 weevils alive in cells.
7								2 adults alive in cells.
9								2 adults and 2 pupæ alive in cells.
12								2 adults alive in cells.
14								1 weevil and 1 larva alive.
16								4 pupæ and 1 larva alive in cell.
19								2 pupæ and 1 larva alive in cell.
Total			4	82		3	67	
Average				20.5			22.3	
Total weevils, both sexes				7				
Average period, both sexes				21.4				

¹ These adults were evidently killed by proliferation.

From this table it is seen that the results of rearings in cotton bolls differ very widely from those in cotton squares. The most marked difference is in the tendency exhibited by the weevils to remain in hibernation in the cells in the bolls. In fact, only seven weevils emerged directly after what might be termed a normal developmental period.

All bolls were retained, and at the close of the experiments on November 10 all were opened and the contents noted. This examination showed that 15 adults had emerged after observations were stopped, 33 adults were alive in cells, 22 adults were dead in cells, 9 pupæ were alive in cells, 4 larvæ were alive in cells, and 3 larvæ were dead in cells. Thus it is seen that 22 adults emerged, 33 remained alive in the cells, and 22 died in them.

The developmental period for the seven weevils which were observed at the time of emergence varied from 17 to 28 days, with an average of 21.4 days. In Texas the *Thurberia* weevils averaged 25 days in cotton bolls. They displayed the same tendency to delay emergence some days after maturity but did not attempt to hibernate in the cell as in Arizona.

Many of the records point to the great irregularity of the development in cotton bolls. In one case where the egg was deposited August 13 a live pupa was found in the boll on November 10, or a total of 58 days for incubation plus larval plus part of pupal period. In another case where the egg was deposited October 1 a live larva was found November 10, or a total of 40 days for incubation plus part of larval period. When it is remembered that under the same conditions adults were produced and emerged in as few as 17 days after egg deposition, these records are all the more striking.

The death of the adults due to proliferation is quite interesting. Five were found which were quite evidently killed by this agency. In these cases the weevils had formed more or less normal pupal cells, but the growth of the tissue broke these and pressed the adults to death. Of course, there was no way to determine how many of the immature stages were killed by this phenomenon, but the number was probably quite high.

IN THURBERIA BOLLS.

The *Thurberia* bolls containing eggs secured in the different series of weevils fed upon this food were placed on moist sand in tumblers and an attempt made to rear adults. In such tests the bolls were always as green and fresh as possible and were selected as seeming best adapted for larval food. Early in the investigation it was quite apparent that a single moistening of the sand in the tumbler would not suffice to keep the boll fit for larval food through the developmental period, so the sand was moistened frequently. In this way what seemed to be the best conditions for development were secured, but, in spite of this, the attempt was almost a total failure.

Thirty bolls containing many eggs deposited from June 30 to October 16 were observed, and only one weevil emerged from the entire lot. This was a male which emerged October 31 from a boll which had received an egg October 1, giving a total period from



FIG. 1.—CAGED THURBERIA PLANTS INFESTED WITH WEEVILS. (ORIGINAL.)



FIG. 2.—CAGES OVER COTTON PLANTS USED IN STUDIES ON WEEVIL ACTIVITY.
(ORIGINAL.)

TYPES OF REARING CAGES SIMULATING NATURAL CONDITIONS,
USED IN STUDIES ON THE BIOLOGY OF THE ARIZONA WILD
COTTON WEEVIL.



deposition to adult emergence of 31 days. At the close of the experiment all bolls were opened and the contents examined. Almost all of them showed not the slightest signs of weevil larval work and only one weevil stage was found. This was a pupa found November 9 in a boll which received an egg October 14.

Thurberia buds were tested in the same manner several times during the season but always with negative results. In fact, it was found exceedingly difficult to induce the weevils to deposit in them.

TESTS OF CAGED WEEVILS ON GROWING PLANTS.

ON THURBERIA PLANTS.

In order to study the activities of the weevils upon Thurberia plants in the field, a large cage was arranged over a plant growing under cultivation at the ranch. (Pl. II, fig. 1.) The plant was nearly 5 feet tall and well laden with buds, blooms, and bolls.

Two male and two female weevils were removed from hibernation cells in the Thurberia bolls August 30 and fed upon Thurberia buds and leaves in captivity until September 14. They were then released in the cage with the growing Thurberia plant.

On September 17 two small buds had fallen to the ground with feeding punctures. On the 21st 6 small bolls, 3 buds, and 2 blooms had fallen, all fed upon by the weevils. Several of the fallen bolls and many still hanging on the plant contained egg punctures.

On October 2 it was noted that a very large proportion of the bolls of the plant had been punctured and many contained eggs or larvæ, but very few squares had been attacked.

The plant stopped blooming about October 10, and at this time many of the bolls had the purplish color characteristic of those infested. No bolls were on the ground, and a rather violent shaking of the plant failed to cause any to drop. On October 31 one male weevil was found active on the roof of the cage. A very careful examination of the plant and trash in the cage failed to reveal any other weevils. The infested bolls were still hanging on the plant.

On January 2, 1915, all bolls were removed from this plant and the cage examined for weevils. No adults, either alive or dead, were found in the trash or on the cage walls. All bolls were examined and the following contents noted: 271 bolls taken from the plant were examined; 123 were uninjured, 115 were injured but contained no weevil stages, 30 contained live adults, and 3 contained 1 dead larva, 1 dead pupa, and 1 dead adult, respectively. Eight bolls found on the ground were examined and 6 were found to show signs of weevil injury, but no stages were present. Of the total of 279 bolls examined, 154 had been injured more or less by the weevils, or an infestation of 55.2 per cent. This indicates what was certainly a great activity on the part of the two females.

The fact that while 154 bolls showed signs of weevil injury, only 30 (19.4 per cent) contained live adults on January 2, indicates a very high larval mortality. Most of the injured bolls containing no stages showed only one or two seeds eaten out by larvæ, though in some the injury was more extensive. Whether or not this high larval mortality is found in nature is open to doubt, but the cage conditions very closely approximated those under which the lower plants and weevils exist. This larval mortality may explain one puzzling point in connection with the interrelation of the *Thurberia* plant and weevil—that is, why the weevil does not multiply entirely out of proportion to the abundance of its very restricted host plant when the females are evidently so extremely prolific in egg deposition.

ON COTTON PLANTS.

In the same manner that these weevils were tested upon growing *Thurberia* plants, others were tested on growing cotton plants. Five cages, three large and two small, were placed over rows of plants about 16 inches tall. These plants were all bearing squares, blooms, and bolls. A general view of these cages is shown in Plate II, figure 2. All weevils were collected feeding on *Thurberia* in the Santa Rita Mountains September 25 and kept without food for four days.

The weevils were introduced into the various cages September 29. The small cages (Nos. 8 and 9) each received two males and two females while the large cages (Nos. 3, 6, and 7) each received four of each sex. Following the introduction of these weevils the cages were examined frequently until October 31. The following is a summary of the injured forms which fell from the plants during this period:

Cage No. 8, 11 small bolls.

Cage No. 9, 14 small bolls, 2 squares.

Cage No. 3, 22 small bolls, 2 squares, and 1 bloom.

Cage No. 6, 13 small bolls, 3 squares, and 1 bloom.

Cage No. 7, 18 small bolls, 1 square.

It is interesting to note that all the egg deposition was in the bolls. In fact there was only a comparatively small amount of feeding on the squares and little more on the blooms. For egg deposition the female seems to prefer bolls from about one-fourth to one-third grown. Some of the smallest of these drop from the plant when the larval injury becomes severe but nearly all remain hanging.

On October 31 a final examination of all cages was made. At this time the leaves and other trash piled in the cage was examined for hibernating adults and the plants were examined for active ones. One weevil was found active on the wall of a cage, one was feeding on a bloom, and one was dead inside the bracts of a boll. One male and one female, both dead, were found at the bottom of a pile of trash.

On January 2, 1915, all bolls were collected from the cages and examined for weevil injury or stages. The results are shown in Table VIII.

TABLE VIII.—Weevil stages found in cotton bolls taken from caged plants, Jan. 2, 1915.

Cage No.	Bolls.		Live weevil stages.			Dead weevil stages.		
	Not injured.	Injured but no weevil stages present.	Larvæ.	Pupæ.	Adults.	Larvæ.	Pupæ.	Adults.
9.....	15	1	.....	.....	.....	.....	.....	.....
8.....	7	8	.....	.....	.....	.....	.....	.....
3.....	11	16	.....	2	3	.....	.....	.....
6.....	5	7	2	1	4	.....	1	.....
7.....	6	2	1	1	6	.....	1	.....
Total.....	44	34	3	4	13	.....	2	.....

The fact that only two weevils had emerged, both from fallen bolls, indicated the strong adherence of the weevil to the cell hibernation habit, even when transferred to cotton. One of the weevils which had emerged was found active on the ground and, judging from its condition, it had emerged only a short time before collection. A comparison of the number of immature stages found in these cotton bolls with that found in *Thurberia* bolls in a similar cage test shows the retarded development under the unnatural conditions of a cotton boll.

PARASITES AND PREDATORY ENEMIES OF THE WEEVIL.

In the course of the season's investigations several hundred infested *Thurberia* bolls were collected at various points in the Santa Catalina and Santa Rita Mountains and the adult weevils were reared. In spite of the great number of these bolls which were utilized, not a single parasite emerged. Not a record of weevil parasitism was made by the writer during the entire season.

Only one case of predaceous insects attacking *thurberiae* was noted. On September 25 in the arroyo below Saw Mill Canyon, Santa Rita Mountains, at about 3,500 feet altitude, three Phymatidæ were observed feeding on adult weevils. These have been determined by Mr. Otto Heidemann as *Phymata erosa* var. *fasciata* Gray (one female) and *Macrocephalus inequalis* Champ. (two males). The latter of these was the more abundant at this time.

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BULLETIN No. 345



Contribution from the Bureau of Entomology
L. O. HOWARD, Chief

Washington, D. C.

PROFESSIONAL PAPER

February 5, 1916

NOTES ON THE PREOVIPOSITION PERIOD OF THE HOUSE FLY, *MUSCA DOMESTICA* L.

By R. H. HUTCHISON, *Scientific Assistant.*

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INTRODUCTION.

During recent years a great deal of emphasis has been laid upon the use of flytraps as a means of reducing and controlling flies. The popularity of trapping is based not only on the immediate results obtained, but also upon the claim that many female flies will be caught before they have laid their first eggs, and that thus the possible number of future generations will be greatly reduced. For much the same reason it has been urged that trapping flies in the early spring is effective in reducing the number of future generations. An apparent justification for this method of control was found in the published records of experiments and observations indicating a rather long period of time between the emergence of the adult fly and the first deposition of eggs.

Entomologists have been aware that these methods of control were founded upon a rather meager scientific basis. Comparatively few accurate data have been published bearing upon the length of the preoviposition period. The necessity of more data on this phase of the life history of the house fly was clearly pointed out by Dr. L. O. Howard (1911), and upon his suggestion work along these lines was begun during the season of 1913. The work has been carried out under the general direction of Mr. W. D. Hunter. A few experiments on the preoviposition period were carried out by the writer during the season of 1913 at Arlington, Va., and others during the spring of

NOTE.—This paper is intended for entomologists and others who are interested in the extermination of house flies.

1914 at New Orleans, La., at which place Mr. T. E. Holloway rendered great assistance. During the summer of 1914 an extended series of experiments was carried out by Mr. A. W. J. Pomeroy. After the severance of his connection with the bureau at the end of October the experiments which he had under way were continued during the fall by Mr. J. L. Webb, and during the winter months the writer continued the work in the greenhouses of the Arlington experiment farm of the Bureau of Plant Industry.

METHODS USED IN THE PREOVIPOSITION EXPERIMENTS.

In the experiments to determine the length of the preoviposition period (i. e., the time between the emergence of the adult fly and the first deposition of eggs) laboratory-bred flies were used. The breeding was carried out in a systematic way, and several strains or "pure lines" were followed out through five or six generations. Most of the strains were started from a small number of larvæ or pupæ found in manure piles, and the first flies to emerge from material thus collected were used as the parents of the strain. In one case, however, a strain was started from a pair of flies taken in coitu on July 25, 1914. Eggs were deposited on August 2, and breeding of this strain was continued through six generations.

The adult flies were kept in small cages. A type of cage found very satisfactory for this work was 22 inches high by 12 inches square. The framework was of soft pine 1 inch square. The top, bottom, and three sides were covered with bronzed screen wire, 16 mesh per inch. The fourth side, or front of the cage, was covered with screen wire about 8 inches down from the top. Below this was a board about 8 inches wide, in which was cut an armhole 5 inches in diameter. A sleeve of closely-woven black cloth was tacked over this. Below the board was fitted a drawer 4 inches deep, in which food and material for deposition were kept. Cages of this size were easily and quickly handled, and any part of the interior of the cage could be easily reached through the armhole, the sleeve preventing the escape of any flies during manipulations. The sliding drawer at the bottom of the cage made it possible to remove the contents and examine them for eggs without permitting any flies to escape. These cages were kept on the shelves of a screened insectary and were protected from the direct rays of the sun most of the day, but were freely exposed to air currents and to the outdoor conditions of temperature and humidity.

Flies were transferred to these cages soon after emergence and supplied with food and media for oviposition. The cages were examined daily; any dead flies were removed and the sex noted at the time of removal. In this way at the end of the experiment the total number of males and females was summed up, and the length of life of each fly in the lot was known. The manure or other medium

was removed each day and examined carefully for eggs. Fresh horse manure was supplied each day, care being taken that the manure was not fly-blown before it was introduced into the cages. This was managed by taking fresh manure from the stables early in the morning and keeping it in covered cans until used, and then examining it before introducing it into the cages. During midsummer the additional precaution was taken of boiling the manure for one-half hour before it was put in the cages. When other media were used for oviposition the same precautions against previous infestation were taken. At the time of the daily examination of the cages, and at other times as opportunity offered, observations were made as to copulations. As a rule a regular routine of observations was followed out with each lot of flies as long as any of them remained alive. In a few cases, however, the flies were killed after the first deposition of eggs in order to provide cage space for the new lots of flies emerging.

When, upon examination of the cages, it was found that eggs had been deposited, these were transferred, together with the medium, to small breeding boxes. These breeding boxes were of wood and very tightly made so that no cracks offered a chance for the escape of migrating larvæ. Boxes of two sizes were used. When the number of eggs was small they were bred out in small boxes measuring 8 by 8 by 10 inches, and for larger lots boxes measuring 12 by 18 by 12 inches were used. In one end of these boxes was an armhole 5 or 6 inches in diameter. Tacked carefully over this was a sleeve of black cloth of close weave. This was kept tightly closed with a rubber band when not in use. The top of each box was covered with a glass plate. Thus any flies could be seen as soon as they emerged.

As soon after emergence as possible the flies were transferred from the breeding boxes to the cages described above. This was done by capturing them in vials introduced through the sleeve, or by connecting the armhole of the breeding box with that of the cage by means of a glass cylinder. When the breeding box was darkened the flies soon found their way into the cage through the cylinder. Sometimes the puparia were collected from a breeding box before any emergence had taken place and put into vials or pill boxes and covered with sand. These were put into cages until emergence had occurred. After the first lot of flies had emerged the remaining puparia were transferred to another cage to obtain a second lot, and so on until all had emerged.

THE PREOVIPOSITION PERIOD.

The preoviposition period was determined in some 70 experiments during the season of 1914. Table I summarizes the results of these experiments, most of which are based on Mr. Pomeroy's notes but which include also some experiments by Mr. Webb and the writer, carried out during the autumn and winter. They have been arranged in the table in the order of the increasing length of the period.

TABLE I.—*Preoviposition period of the house fly, Musca domestica.*

Lot number.	Food of larvæ.	Food of adults.	Number of adults in lot.		Date of emergence.	Pre-oviposition period.	Average mean temperature.	Longevity.		Remarks.
			Male.	Female.				Minimum.	Maximum.	
						Days. ¹	° F.	Days.	Days.	
1	Moist bran.....	Banana, water, manure.....	(?)	(?)	Aug. 18, 10.30 a. m. to Aug. 19, 9.30 a. m.	2½	82.5			All killed Aug. 24.
2	do.....	Banana, corn syrup, rotten potato.	(?)	(?)	Aug. 17, 3.30 p. m. to Aug. 18, 10.30 a. m.	3	82	.....	.....	
3	do.....	Banana, water, manure.....	(?)	(?)	Aug. 19, 9.30 a. m. to 4.15 p. m.	3	80.6	.....	.....	
4	Manure ²	Banana, water, manure and bran.	4	3	July 14.....	3	79.2			2 males escaped.
5	Moist bran.....	Corn syrup, water, manure..	(?)	(?)	Aug. 17.....	4	82	7	22	
6	Manure one-half, bran one-half.	Corn syrup, water, rotten potato.	(?)	(?)	Aug. 19.....	4	79.4	6	(?)	
7	do.....	Brown sugar, water, manure.	11	5	Aug. 28.....	4	74.5	1	54	In greenhouse. Fungus killed most of these flies.
8	Manure in compost heap.	Banana, water, manure.....	15	7	July 21, 12 m., to July 22, 2 p. m.	4	82.1	3	43	
9	Manure one-half, bran one-half.	White sugar, water, manure.	(?)	(?)	Aug. 29, 12 m., to Aug. 30, 11 a. m.	5	74.3	5	51	
10	Bread moistened with milk.	Banana, water, manure and bran.	(?)	(?)	July 20 to July 21, 1 p. m.....	5	81.6	6	38	2 males escaped.
11	Manure in compost heap.	Banana, water, manure.....	3	6	July 21.....	5	81.6	3	(?)	
12	(?).....	Brown sugar, water, manure.	(?)	(?)	Aug. 31, 12 m., to Sept. 1, 12 m.	6	72	3	42	
13	Manure in compost heap.	Banana, beer, manure.....	(?)	(?)	June 22, 4 p. m., to June 23, 10 a. m.	6(?)	79.9	10	29(?)	In greenhouse. Fungus killed most of these flies.
14	Manure.....	Banana, water, manure, rotten potato	(?)	(?)	Aug. 11.....	6	74.5	.....	.....	
15	Manure one-half, bran one-half.	Brown sugar, water, manure.	(?)	(?)	Aug. 29.....	6	74	2	52	
16	Manure one-half, crushed oats one-half.	do.....	14	4	Oct. 24 to Oct. 26.....	6		5	26	All flies killed on Aug. 3.
17	Manure one-half, bran one-half.	Corn syrup, water, manure..	(?)	(?)	Aug. 17, 12 m. to 3.30 p. m..	6	79.7	8	19+	
18	Manure.....	Banana, water, manure.....	(?)	(?)	Sept. 2.....	6	69.2	10	22+	
19	Manure in compost heap.	Bread, beer, manure.....	3	102	June 22, 4 p. m., to June 23, 10 a. m.	7	78.5	2	29	All flies killed on Aug. 3.
20	Pig manure, bran mixture.	Banana, water, manure.....	63	41	July 24, 2.30 p. m., to July 25, 11.30 a. m.	8	72	.....	.....	
21	Manure.....	Milk, bread, manure.....	3	40	June 22, 4 p. m., to June 23, 10 a. m.	8	78.4	3	25	

[illegible]

³Sex not determined.

² The term "manure" means "horse manure" unless otherwise stated.

¹ Approximate.

TABLE I.—*Preoviposition period of the house fly, Musca domestica*—Continued.

Lot number.	Food of larvae.	Food of adults.	Number of adults in lot.		Date of emergence.	Pre-oviposition period.	Average mean temperature.	Longevity.		Remarks.
								Mini-	Maxi-	
			Male.	Female.			° F.	Days.	Days.	
46	Manure one-half, bran one-half.	Corn sirup, water, bread, manure.	9	21	July 24, 1 p. m., to July 25, 11 a. m.	Days ¹ 14	80	9	38	
47	Manure.....	Brown sugar, water, manure.	52	17	Sept. 22.....	14	61.2	6	35	
48	Manure one-half, crushed oats one-half.	do.....	16	7	Sept. 27, a. m., to Oct. 1, 2 p. m.	14	62	10	31	
49	Manure.....	Banana, water, manure.....	20	15	Sept. 25, 3 p. m., to Sept. 26, 3 p. m.	14	61.5	14	31	
50	Manure one-fourth, crushed oats three-fourths.	Brown sugar, water, manure.	97	59	Sept. 25.....	14	60.6	3	32	
51	Manure.....	Banana, water, manure.....	(?)	(?)	Sept. 7, 2 p. m., to Sept. 9, 12.30 p. m.	14	62.6	4	45	
52	Manure, previously boiled.	do.....	(?)	(?)	Sept. 8.....	14	62.5	4	36	
53	Manure.....	Brown sugar, manure, rotten potato.	8	8	Sept. 2, 4.30 p. m., to Sept. 3, 4 p. m.	14	62.5	1	46	Mice destroyed flies or permitted them to escape on thirty-first day. No food for adults before Oct. 1, 3 p. m.
54	do.....	Brown sugar, water, manure.	(?)	(?)	Oct. 5, 9 a. m., to Oct. 6, 12 m.	14	62.3	8	31+	
55	Manure one-fourth, crushed oats three-fourths.	do.....	17	20	Sept. 26 to Oct. 1, 3 p. m....	15	66.7	9	24	
56	Manure one-half, crushed oats one-half.	do.....	80+	91+	Sept. 25, 2.30 p. m., to Sept. 26, 3 p. m.	16	62.5	2	51	
57	Bran-pig manure mixture.	Corn sirup, bread, manure...	18	13	July 24, 1 p. m., to July 25, 11 a. m.	16	75.2	10	40 (?)	
58	Manure.....	Brown sugar, water, manure.	? 6	? 2	Oct. 15 to Oct. 21, 1 p. m....	16	.....	9	32	Cage started Oct. 21. Kept in greenhouse.
59	do.....	Grape juice, fresh manure...	(?)	(?)	Sept. 2, 4.30 p. m., to Sept. 3, 3.30 p. m.	17	63	2	21	
60	do.....	Banana, water, manure.....	21	10	Sept. 5, 12 m., to Sept. 7, 2 p. m.	17	64.1	8	43	
61	do.....	Brown sugar, water, manure.	94+	34+	Sept. 22, 3 p. m., to Sept. 23, 4 p. m.	17	61.6	5	31+	
62	Manure one-fourth, crushed oats three-fourths.	White sugar, water, manure...	21	13	Sept. 24.....	17	61.5	1	36	Last male killed Oct. 24.

63	Manure.....	Brown sugar, water, manure.	(?)	(?)	Aug. 6 to Aug. 7, 11 a. m.,	17	78.7	1	(?)
64	Manure.....	Banana, water, manure.....	(?)	(?)	Sept. 25, 8 a. m., to Sept. 26, 2 p. m.	18	59.1	13	29
65	do.....	Brown sugar, water, manure.	6	8	Oct. 4.....	19	63	19	30
66	Manure one-half, crushed oats one-half.	do.....	67	50	Sept. 24.....	19	61.7	4	40
67	Manure.....	do.....			Sept. 22.....	20	63.5	3	42
68	do.....	White sugar, water, manure.	16	9	Sept. 24.....	22	61	4	40
69	do.....	White sugar, vanilla extract, manure.	7	6	Sept. 2.....	23	65.1	6	41

¹ Approximate.TABLE II.—*Preoviposition period of the house fly; tests with isolated pairs.*

No.	Food of larvæ.	Food of adults.	Date of emergence.	Taken in coitu.	Emergence to copulation.	Copulation to oviposition.	Total preoviposition period.	Average mean temperature.	Number of eggs per deposition.	Longevity of—		Remarks.
										Male.	Female.	
1	Manure.....	Corn sirup, water, manure.	Aug. 11.....	Aug. 14, 2.30 p. m.	Days, 3	Days, 6	Days, 9	° F. 71.2	2	Days, (1)	Days, (1)	
2	do.....	Banana, water, manure.	do.....	do.....	3	6	9	71.2	1	96	6	13
3	do.....	do.....	do.....	Aug. 14, 11.30 a. m.	3	6	9	71.2	1	25	18	21
4	do.....	do.....	do.....	do.....	3	6	9	71.2	2	33	14	15
5	Pig manure, bran mixture.	do.....	July 24, 2.30 p. m., to July 25, 11.30 a. m.	July 31, 10.40 a. m.	6	3	9	73.7	1	87	13	2 (?)
6	Manure.....	Sugar, bread, water, manure.	July 23, 3.15 p. m., to July 24, 11 a. m.	July 28, 2.30 p. m.	4	5	9	72.9	1	28	10	2 (?)
7	(?)	Banana, water, manure.	(?)	July 26, 2.30 p. m.	(?)	8	(?)	72	1	40	34	3 14

¹ At least 16.² At least 13.³ Days after copulation.

No records of female after Aug. 7.

Do.

Many attempts were made by Mr. Pomeroy to keep isolated pairs of flies under as natural conditions as possible in order to obtain not only the preoviposition period but also the number of depositions per fly and the number of eggs per deposition. The usual method was to remove from a lot of laboratory bred flies the first pair which were found in copulation. After transfer to a separate cage they were supplied with food and a medium for oviposition and were kept under observation in much the same way as the larger lots. The results of the tests with isolated pairs are summarized in Table II.

The fact that only 7 out of some 30 tests gave any positive results points to the difficulties in obtaining significant data from experiments performed under artificial conditions.

The shortest preoviposition period was about two and one-half days (Table I, lot No. 1). Mr. Pomeroy's original notes on this lot show that the "flies emerged some time between August 18, 10.30 a. m., and August 19, 9.30 a. m.," at which time they were "transferred to cage and supplied with banana, water, and fresh manure. Examined August 20 at 3.30 p. m. No eggs were found. Fresh manure supplied. August 21, at 1 p. m., two clusters of eggs were found, 80 to 90 eggs in each cluster." Now, if the flies which deposited these eggs had emerged on the afternoon of the 18th the preoviposition period was a little longer than two and one-half days. If they had emerged during the morning of the 19th before 9.30 a. m. the period was a little less than two and one-half days. Other remarkably short periods are to be found in the three 3-day periods shown in the table, and in the four 4-day records. It is reasonable to suppose that if these short periods were found under artificial experimental conditions they would be not at all uncommon under natural conditions.

The longest period was one of 23 days (Table I, lot No. 69). In general it may be said that the shortest records occurred in mid-summer and that the longer ones were obtained during the autumn months. It is true that some long periods were found in summer, e. g., a 14-day and a 16-day record in July, but no short records were ever found during the autumn months. In other words, the length of the preoviposition period is greatly influenced by the temperature. A study of Table I will show that the arrangement according to the increasing length of the period corresponds in a rough way with the order of the decreasing mean temperatures of those periods. The relation between the temperature and the length of the preoviposition period is made clearer in the correlation table (Table III), in which the columns give the preoviposition period in days and the rows represent 2° intervals of temperature.

TABLE III.—Correlation between the average mean temperature and the length of the preoviposition period of the house fly.

Average mean temperatures in 2° intervals.	Length of the preoviposition period in days.																						
	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	
82° to 84°	1		1																				
80° to 82°		2	1	2									1										
78° to 80°		1	1		2	1	1	1								1							
76° to 78°										1													
74° to 76°			1	1							2				1								
72° to 74°					3		1	2	1			1											
70° to 72°								4															
68° to 70°					1				1														
66° to 68°								1				2			1								
64° to 66°								2	1	4						1						1	
62° to 64°												1	4		1	1		1	1				
60° to 62°										1	3		4			2				1			
58° to 60°																	1						

To represent this relation graphically the average of the average mean temperatures for all the records of a given length has been taken, and the following figures obtained:

Length of period.	Number of records.	Average of the average mean temperatures.
<i>Days.</i>		<i>° F.</i>
2½	1	82.5
3	3	80.9
4	4	79.5
5	3	79.2
6	6	74.9
7	1	78.5
8	2	75.2
9	10	71.2
10	4	67.1
11	6	65.8
12	8	68.1
13	1	67.3
14	9	63.9
15	1	66.7
16	2	68.8
17	5	65.8
18	1	59.1
19	2	62.3
20	1	63.5
22	1	61
23	1	65.1

Figure 1 shows the curve obtained by plotting these figures. The broken line in the figure is the hyperbole which is the nearest approach to the actual experimental curve. If it is true that "the curve expressing the increase in rate of development is a true hyperbole" (Peairs, 1914), one must seek for an explanation of the many deviations from the true curve which are seen in the experimental curve. It is of course probable that if the accumulated effective temperature for each period were worked out, the resulting curve would show a much closer approach to a true hyperbole.

It is not necessary to point out that there were several other variables among the conditions of these experiments. For example, humidity is no doubt an important factor, but the lack of complete and accurate records of the relative humidity prevents making any statistical analysis of its influence on the length of the preoviposition period.

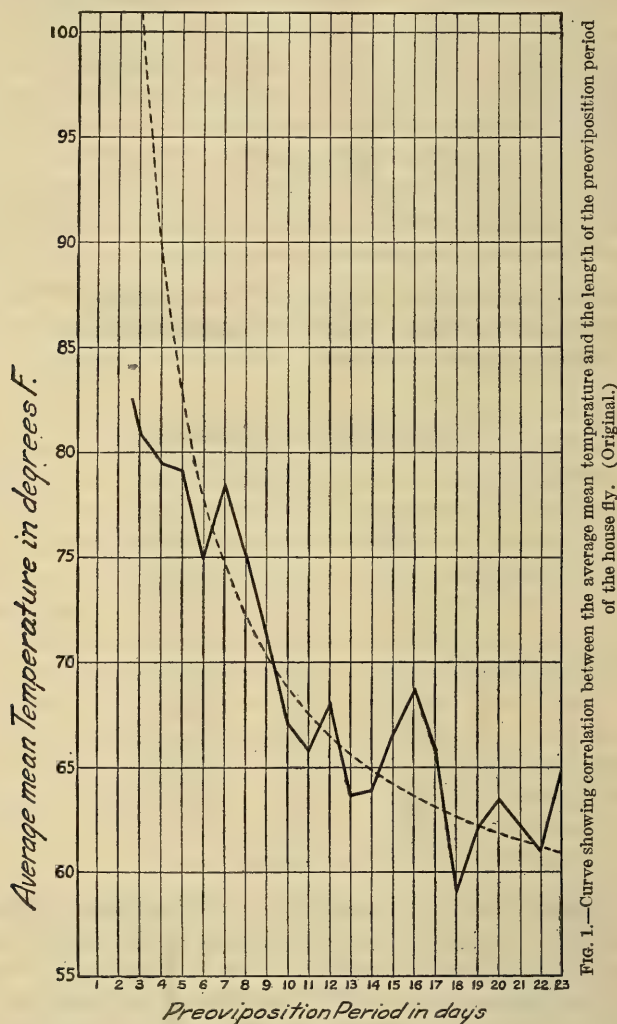


Fig. 1.—Curve showing correlation between the average mean temperature and the length of the preoviposition period of the house fly. (Original.)

It is interesting to note that Bishopp, Dove, and Parman (1915), in experiments at Dallas, Tex., obtained a 4-day record at an average mean temperature of 87.5° F., while the 4-day records at Arlington, Va., averaged 79.5° F. This and other differences between their results and those recorded in the present paper may in large part be due to the differences in the relative humidity of the two localities.

Bishopp, Dove, and Parman are doubtless correct in saying that in general "increased humidity seems to hasten egg laying."

The present results agree also with the Dallas observations in showing that the food supply of the adult flies has an important influence on the length of the preoviposition period. Banana, water, and manure was found to be a favorable combination in these experiments. Lack of moisture always proved fatal to flies, and without food they die within two or three days.

Yet temperature, humidity, and food supply are not the only factors which influence egg laying. If Table I be examined, such apparently contradictory results as an 8-day record at an average mean temperature of 72° F. (see No. 20) and a 12-day record at an average mean temperature of 76° F. (see No. 39) will be found. Mr. Pomeroy has suggested, and the writer is strongly of the opinion, that the kind and quality of the larval food is partly responsible for such apparent discrepancies. It is a well-known fact that the amount and kind of larval food have a marked influence on the size of the resulting adult flies, and there is no reason to doubt that the physiological activities of the adult are likewise affected. It appears in Table I that most of the shorter preoviposition records were obtained with flies which had been bred from larvæ fed on moist bran or a bran-manure mixture. From media which fermented less actively than these, or which were allowed to dry out, or were too small in quantity, the resulting flies were not only small but often failed to oviposit at all and usually lived a shorter time than large flies under the same conditions. Some larvæ bred exclusively on rotten potato produced a small race of flies which did not oviposit, due perhaps to the preponderance of starch in their diet. Griffith (1908) observes that small flies are incapable of reproduction.

In the experiments with isolated pairs of flies only 7 out of 30, or about 24 per cent, gave any positive results as regards the deposition of eggs. In the other experiments where a number of flies (8 to 200) were used in each lot, 70 out of 110, or about 63 per cent, gave positive results. It is possible that this may be accounted for by what may be called a psychological factor. The habit of the adult females of associating in large numbers in one favored spot in depositing eggs has been previously pointed out (Bishopp, Dove, and Parman, 1915), and it is probable that the isolation of a pair of flies is an abnormal condition which has its inhibiting effect.

As regards the number of depositions, the Arlington observations again agree with those made at Dallas in that it was impossible to obtain more than two lots of eggs from a single female, but this does not prove, of course, that under normal conditions the adult fly can not oviposit oftener. Griffith (1908) gives no details of experiments

or observations in support of his statement that the fly repeats the process of egg laying at intervals of 10 to 14 days till four batches have been laid. The largest number of eggs per deposition in these experiments was 96 and the smallest 25.

Recent experiments have placed the knowledge of the preoviposition period on a more complete basis and have shown that the period is considerably shorter than was previously thought to be the case. Dr. C. G. Hewitt publishes the results of experiments performed by him in England in 1907, in which the period was found to be 14 days. Griffith (1908) states that the adult fly can begin to lay eggs 10 days after emergence. Bogdanow (1903) publishes the results of some breeding experiments with the house fly. In a table given in his article it appears that in one experiment the first flies emerged on August 12 and the first eggs laid by these flies were found on August 18—a preoviposition period of 6 days.

COPULATION.

Observations on the copulation of flies were necessarily not continuous, but of chance observations there were a large number, and they show that copulation may occur as early as one day after emergence. There are three records of copulations taking place on the second day after emergence, and 14 records of copulations on the third day after emergence. The greatest number of records fall on the third to sixth days, inclusive. Copulations were observed as late as the twenty-sixth day, and in an experiment during the winter, when a lot of flies was kept in a stable where the air temperature ranged from 30° to 60° F., one copulation was observed on the forty-seventh day after emergence. The air temperature at the time was 55° F. During the autumn a number of copulations were observed taking place when the air temperature was 55° F., but no sexual activity was ever seen at temperatures lower than 55°.

LONGEVITY.

As stated, the daily routine of observations on the various lots of flies included the removal of dead flies and the recording of their sex and length of life. The experiments during the summer and fall of 1914 include records of some 3,000 flies. The longevity of these flies varied from 1 day to 54 days. The arithmetical mean of all these records was found to be 19+ days. This may perhaps be taken as the average for both sexes at all seasons. In midsummer the length of life is often much less and during the spring and autumn months is considerably more. In one hibernation experiment, in which flies were kept in a stable at temperatures varying from 30° to 60° F., a few lived as long as 70 days. This record was not included in calculating the mean longevity.

SUMMARY.

From the experiments reported in this paper it is seen that the shortest record for the preoviposition period was one of about 2½ days and the longest, one of 23 days, with most of the records falling on the fourth, fifth, sixth, ninth, twelfth, and fourteenth days after emergence.

It is shown that the temperature has a very decided influence on the length of the period.

Other factors influencing this period are humidity, the kind and quality of the food of the adults, and the kind and quality of the larval food with its resulting effect on the size and physiological condition of the adults. In the experiments with isolated pairs of flies very few results were obtained, which suggests that the association of a number of females in the process of egg laying is the normal habit and that isolation has an inhibiting effect.

Copulations were observed as early as the first day after emergence and as late as the forty-seventh day. No copulations have been noted when the air temperature has been below 55° F.

The maximum record for longevity was 70 days, and the minimum was one day or less. The average of the records of some 3,000 flies was slightly over 19 days.

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PROFESSIONAL PAPER

February 21, 1916

HOME PROJECTS IN SECONDARY COURSES IN AGRICULTURE.¹

By H. P. BARROWS, *Assistant in Agricultural Education.*

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INTRODUCTION.

Elementary agriculture is taught in a large number of high schools in much the same manner that academic subjects are taught. It is evident that the aim in these classes is to arouse interest and to give information about farming. During the last two or three years, however, there has been a remarkable increase in the number of schools which are conducting more extensive courses in agriculture. Most of the schools which devote more than one year to this subject employ a teacher who has had special training in agricultural subjects. A recent investigation made by the States Relations Service revealed the fact that the predominating aim in these schools is vocational—i. e., that they are attempting to train their students for actual farm practice. In the attempt to make the teaching of agriculture practical teachers and school officers have met with difficult problems. Many have felt that the only solution of the problems of practical work is for the school to own land upon which the student might see a demonstration of principles and put into practice what he learns. The school farm has not solved the problem satisfactorily for all and has presented new problems which are

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NOTE.—This bulletin gives information regarding the home-project plan of teaching agriculture and is of interest primarily to teachers in secondary rural schools.

demanding attention.¹ Many teachers and investigators have felt that a wider use should be made of the home farm in the teaching of agriculture. It is the aim of this bulletin to give suggestions toward making the home farm a more definite factor in agricultural instruction through what is known as the home-project plan. In his study of this plan the writer has gleaned many suggestions from the work done in Massachusetts and New York.

DEVELOPMENT OF THE HOME-PROJECT IDEA.

The part-time method in industrial education.—In recent years considerable attention has been given to European methods of vocational education, with a result that new methods have been introduced into this country and more attention has been given methods already used here to a limited extent. One of these methods is the part-time cooperative plan of industrial education. Under this method there is cooperation between the school and the factory or industrial center, so that students may spend part of their time in school and part of their time in the factory or shop. The work of school and shop are supplementary to each other. As the part-time idea is an effort to bring the school and factory together, so the home-project plan is an effort to bring the home and school together. The farm may be considered as the industrial center of the country. The home-project plan may be considered as an effort to utilize this center in agricultural education.

The project idea in science teaching.—Agriculture has followed science in its methods of teaching. As science has been taught in the high school mostly through the textbook and laboratory method, so the study of agriculture has been a study of books accompanied by laboratory exercises. In recent years progressive teachers of science have made an effort to break away from textbooks and formal laboratory work and adapt their teaching to the environment of their students. Students have been assigned special problems at home which would involve the principles studied at school. These problems were called projects. When electricity was studied in a certain school one student was given the wiring of his father's house as a project in which he could apply the principles learned. Another student made a study of the germination of seeds and other problems involved in his home garden in connection with a study of plant growth. It was apparent that if this method were successful in science teaching that it could be applied even more successfully in the teaching of agriculture.

¹ For a general study of the problems arising in the use of land in connection with agricultural teaching, see the following reports of a special committee appointed to investigate the subject by the American Association for the Advancement of Agricultural Teaching: U. S. Bur. Ed. Bul. 522 (1913), pp. 24-39; 601 (1914), pp. 49-76. See also *The Use of Land in Teaching Agriculture in Secondary Schools*, U. S. Dept. Agr. Bul. 213 (1915).

The Massachusetts home-project plan.—Massachusetts was the first State to give State aid to vocational agriculture based upon the home-project plan. In 1911 the State legislature made State funds available for the establishment of vocational agricultural schools and departments according to plans submitted by the Massachusetts Board of Education. Departments of vocational agriculture may be established in high schools and if approved by the State board of education the communities which maintain them are reimbursed to the extent of two-thirds of the salary of the agricultural instructor. This instructor must be a specially qualified person who devotes his entire attention to agriculture.

Teachers are employed in these schools and departments for the entire year. The summer time is spent in supervising the home projects of students. Usually some time is allowed in the winter for a vacation and for professional improvement. The class work is centered around the home project, which is required of each agricultural student. Before the boy enters the work parents must agree to furnish the facilities for carrying out the particular instructions of his teacher. In each district where vocational agricultural training is established an advisory committee consisting of five members is appointed to cooperate with the agricultural instructor in adapting the agricultural training to the particular needs of the locality.¹

Other States giving State aid.—Since the home-project plan was introduced into Massachusetts, the States of New York, Pennsylvania, New Jersey, and Indiana have given State aid to vocational agriculture based upon this plan. In all of these States distinction is made between agriculture as ordinarily taught in the high school and vocational agriculture. The use of State funds in each of the States is dependent upon organization and supervision by State officials.

Extension of the project idea.—The success of the home-project plan in States which are making it the basis of their instruction in vocational agriculture has led to a wide interest in the plan and to an application of the idea in schools of other States. In many sections agricultural students are doing practical work in clubs which have a relation more or less close to their school work. Many schools in their effort to make the teaching of agriculture practical have secured land to be used by the students. These school farms have not proved satisfactory in all cases. Other schools either have not deemed it wise or have not seen their way clear to purchase or lease land for school use. All of these schools should be interested in a plan to utilize the home farms of the students in connection with the teaching of agriculture.

¹ For an exposition of the Massachusetts plan, see U. S. Bur. Ed. Bul. 579 (1914).

Lack of unity in definition.—In many sections where teachers talk of projects there seems to be a lack of understanding of the plan and a lack of unity in definition of the term. According to some teachers any effort toward giving their work a practical turn is termed a project. Others have used the word in lieu of "practicum," so that simple laboratory exercises are spoken of as projects. In a general way a project is anything mapped out or planned to be done. The term has been used for years by this department in connection with its work and that of the experiment stations. The term, "home project," however, has come to have a special meaning in connection with the teaching of agriculture. It is essential that this meaning be agreed upon before plans for carrying out the idea are discussed.

ESSENTIALS OF A SUCCESSFUL PROJECT.

Definition.—The following definition of a home project is suggested: The term "home project" applied to instruction in elementary and secondary agriculture includes each of the following requisites: (1) There must be a plan for work at home covering a season or a more or less extended period of time; (2) it must be a part of the instruction in agriculture of the school; (3) there must be a problem more or less new to the pupil; (4) the parents and pupil should agree with the teacher upon the plan; (5) some competent person must supervise the home work; (6) detailed records of time, method, cost, and income must be honestly kept; and (7) a written report based on the record must be submitted to the teacher. This report may be in the form of a composition or a booklet.

A project to cover an extended period at home.—A distinction should be drawn between a project and a simple exercise used as a practicum to illustrate some principle, or for the purpose of increasing skill in some operation of farm or shop. A project, to be worthy of the name, should involve skill in many operations and the application of a number of principles. To accomplish this it should cover a branch of farming that will extend over a comparatively long period of time. The testing of seed corn may be cited as an example of a simple laboratory exercise performed at school. The stringing of seed corn would be a suitable home practicum, the aim of which would be to acquire skill in a useful operation. The growing of an acre of corn would involve both of these operations and many others, hence it would be a worthy project.

It is obvious that if the term "home project" is applied in a strict sense the work should be carried on at home. In case a suitable project may not be arranged for a student at home, there should be no objection to the student working away from home. If this work

can be properly correlated with his course of study and meet other requirements of a project there should be no objections to accepting it as a substitute for a home project.

The project to be a part of the instruction in agriculture.—The project should have a definite relation to the course of study. If the student is taking a course in farm crops his project should be along the line of crop production; if he is studying animal husbandry, his project should be connected with the care of animals; projects in fruit growing or vegetable gardening may accompany courses in horticulture; and if a special course in farm management is given, special problems of management should be assigned as projects.

Boys and girls not taking the course in agriculture may be induced to take up some special phase of practical agriculture at home, but such work does not come within the definition of a project. A student while taking a course in animal husbandry may start to keep records of the home herd in connection with a dairy project, his interest may cause him to continue the work the following year while he is taking a course in fruit growing, but some work pertaining to the production of fruit should then constitute his main project.

The project to present a new problem.—It should be borne in mind that the primary aim of the home project is educational. A project should be considered in the light of what the student may learn from it in principle and practice. A student may grow an acre of corn year after year and continue to learn something new, but if the work of the first year has been properly planned and supervised it will have far greater educational value than in the succeeding years. After growing corn one year the student may better take up some other crop or, better still, an entirely different phase of farming.

Pupil, parents, and teacher unite upon plan.—The home project when properly administered is an excellent means of bringing the home and school together in their educational problems. The teacher should know the home conditions surrounding the student and should not attempt to plan a project without first getting the consent of the parents. Not only should their consent be obtained, but every attempt should be made to secure their hearty cooperation. Whether a written agreement is made or not will depend upon the relation of the project to the plan upon which the agricultural course is conducted. In productive projects and in other projects as far as possible, the student should be given entire responsibility regarding the work and should have a financial interest in its outcome. If the student is using his father's land or live stock, he should pay rent or interest on a fair valuation. He should work with an understanding that he will participate in the profits, if they are not all to be his, and at the same time feel that he will be responsible for any losses.

Competent supervision essential.—Supervision is necessary in order that those in charge may be sure the work is carried out as outlined. It is even more essential that some one take an active interest in aiding with problems which may arise, and in giving encouragement. Where it can be arranged it will prove most satisfactory as a rule to have the teacher who is conducting the class work supervise the projects connected with the courses given. The summer season is the most important time for most projects, hence in States where the teaching of agriculture is based upon the home project, teachers are employed for the entire year. If any vacation is allowed them it is taken in the winter. Effective supervision means frequent visits to the homes of the students. In districts where the students are scattered over a wide area, some special means of transportation will be essential to efficient service.

Detailed records to be kept.—A valuable part of the training secured in connection with carrying out a project will be obtained in the keeping of accurate records and accounts. It will be helpful, if not absolutely necessary, to give a few lessons in elementary cost accounting before the work is begun. The record should cover points learned in connection with study relating to the project as well as experience gained in practice. In keeping accounts such items as rent of land and interest on investment should not be overlooked. Accurate account should be kept of the time expended and charges and credits made upon a fair basis. Accuracy and fairness are especially important in the keeping of accounts where there is any contest feature in conducting the projects.

The following record blank for a potato project may be adapted to other crops. It is suggestive of forms which may be used for other kinds of projects.

Record blank for potato project.

SOIL PREPARATION.

Character of soil.....	Crop for 5 years past.....
Date of plowing.....	Dates of harrowing.....
Implement used.....	Implements used.....
Depth plowed.....	Cost of harrowing.....
Cost of plowing.....	Condition of land when planted.....

CROP PLANTING AND CULTIVATION.

Variety of potatoes planted.....	Kind of fertilizer.....
Kind of seed.....	Amount of fertilizer per acre.....
Cost of seed and planting.....	Cost of fertilizer.....
Depth of planting.....	Dates of cultivation.....
Distance of planting.....	Implements used.....
Percentage of stand.....	Cost of cultivation.....

HARVEST AND YIELD.

Date of digging.....	Yield in marketable potatoes.....
Method of digging.....	How disposed of.....
Days from planting to digging.....	Cost of harvest and marketing.....
Total yield.....	
Remarks.....	

Approved:

.....	.....	Teacher.
.....	Student	Age.....
Post office.....		School.....
County.....		

Estimate the rental of your land and your time at a fair valuation. Count all commercial fertilizers at actual cost and barnyard manure at what it would bring in the district.

EXPENSES.

Rent of land.....	\$.....
Preparation of seed bed:	
Horse labor.....	.....
Student's labor.....	.....
Cost of seed.....	.....
Cost of planting:	
Horse labor.....	.....
Student's labor.....	.....
Cost of fertilizer.....	.....
Cost of cultivation:	
Horse labor.....	.....
Student's labor.....	.....
Cost of digging:	
Horse labor.....	.....
Student's labor.....	.....
Cost of sacking, storing, and marketing.....	.....
Total cost.....	\$.....

RECEIPTS.

Total value of marketable potatoes, bushels, at	\$.....
Value of cull potatoes, bushels, at .....	.....
Value of potatoes kept for seed, bushels, at .....	.....
Total receipts.....	.....
Net profit.....	.....

A written report to the teacher.—The records kept are to be made the basis of a written report to the teacher upon the completion of the project. This report may be in the form of a composition, or it may be somewhat of the nature of a thesis. There is an excellent opportunity in this work to correlate the work in agriculture with the work in English. Teachers and supervising officers will find among these reports some which may be used to advantage in arousing interest in the work. Photographic records will be found very useful for the same purpose.

SOME PROJECT OUTLINES.

Classification of projects.—If a class in agriculture should undertake to build a henhouse upon the school grounds or to prune or spray a neighboring orchard, such work may be called a class project or a group project. In this discussion individual home projects as previously defined are considered. Home projects may be grouped according to their chief aim as follows:

Production projects.—Those projects in which the chief aim is to produce any agricultural product at a profit.

Demonstration projects.—Those projects in which the chief aim is to demonstrate materials and methods in agricultural practice. (If there is any uncertainty as to results which should be expected it may be better to call such demonstrations experimental projects.)

Improvement projects.—Those projects in which the chief aim is to make improvement with hope of little immediate returns.

Management projects.—Those projects in which the chief aim is to apply efficiently the general principles of farm management.

The project study outline.—Although teachers may make outlines to be used by the students as guides in their study and work, it may be better to have students make their own outlines. These outlines may be arranged with one of the following purposes in mind: (a) As a guide to a study of the subject, (b) as a basis for a practical plan for carrying out the project, and (c) as a combination of both study guide and working plan. The latter idea has been used in the outlines which follow. These outlines cover a range of projects and are offered as suggestions of one method of treatment. The teacher may aid the student by indicating in the outline references which students may use in finding answers to the questions asked.

POTATO PROJECT STUDY OUTLINE.

GROWING AN ACRE OF POTATOES—A PRODUCTION PROJECT.

- I. Shall I grow potatoes for my project?
 1. Is this section adapted to potatoes?
 2. Is my soil suitable for growing potatoes?
 3. Can I control all pests and diseases which prevail in this district?
 4. Is there a good prospect for potatoes paying a profit this year?
- II. What shall be my aim in potato production?
 1. Shall I grow late potatoes for winter use?
 2. Shall I grow early potatoes for the market?
 3. Shall I grow potatoes for seed?
 4. Shall I make a combination of the aims above?
 5. To which is my soil best adapted?
 6. Which offers the greatest prospect for returns?
 7. Which will fit in best with my work at home and at school?

III. How shall I prepare my land?

1. Has the previous crop and treatment of the land left it in suitable condition?
2. What crop should I use to prepare the soil for a future potato crop?
3. When and how should barnyard manure be used for a crop of potatoes?
4. Can I afford to use commercial fertilizers on my potato land; if so, how much of what kind?
5. When shall I plow and how deep?
6. What other preparation is necessary?

IV. What seed shall I plant?

1. What varieties are grown in this district?
2. Are there better varieties which would suit local conditions and my particular needs?
3. Shall I buy home-grown seed?
4. Shall I pay extra for selected seed?

V. How shall I plant my seed potatoes?

1. When shall I plant?
2. Shall I let my seed sprout before planting?
3. How shall I cut the seed potatoes?
4. Is there any danger from scab; if so, how shall I treat my seed potatoes to prevent infection?
5. What is the proper depth and distance for planting?

VI. How shall I cultivate my potatoes?

1. What are the purposes of cultivation which I should bear in mind?
2. What cultivation may they need before they are out of the ground?
3. Shall I practice level culture or the hill method?
4. What type of cultivator will serve my purpose best in row cultivation?
5. When and for what purpose shall I use a hoe?
6. What particular weeds must I guard against?

VII. How can I control insect pests and potato diseases?

1. What are the prevalent insect pests and diseases of potatoes in this district?
2. What spray mixture will kill a biting insect like the Colorado potato beetle?
3. How shall I make Bordeaux mixture if fungus diseases are threatening?
4. Can I use a combination that will destroy insects and prevent disease?
5. What kind of spraying outfit will best serve my needs?
6. Will it pay me to buy a spray outfit or hire my spraying done?

VIII. How shall I select my seed potatoes for next year?

1. Shall I mark some of the promising plants and make a hill selection?
2. Shall I depend upon selection from the bin or upon the purchase of selected potatoes?

IX. How shall I handle my potato crop?

1. When shall I harvest my potatoes?
2. Shall I dig my potatoes by hand, use a plow, or hire some one to dig them by machinery?
3. Shall I store my potatoes or market them direct from the field?
4. How shall I grade them?
5. What shall I do with my culls?

PIG PROJECT STUDY OUTLINE.

RAISING PIGS ON OWN ACCOUNT—A PRODUCTION PROJECT.

- I. Shall I raise pigs for my project?
 1. Do I like pigs?
 2. Is this section suited to the profitable production of pork?
 3. Do pigs fit in well with the farm management plan?
 4. Is cholera or any other disease likely to prevent profits?
- II. What shall be my aim in raising pigs?
 1. Shall I feed one or more pigs during the summer to market in the fall or winter?
 2. Shall I aim toward building up a pure-bred herd for breeding purposes?
 3. Shall I make a combination of the aims above?
- III. How shall I get a start?
 1. Shall I buy one or more young pigs?
 2. Shall I buy a sow which has been bred?
 3. Shall I buy pure-bred pigs or grades?
 4. What breed shall I buy?
 5. Do I know the points of a good pig?
- IV. Can I give breeding animals proper management?
 1. Do I know how to manage the boar and sow at breeding time?
 2. Can I give a brood sow the proper care?
 3. Can I manage sow and pigs properly at farrowing time?
- V. How shall I care for young pigs?
 1. What attention do they need before weaning?
 2. What care and feed shall I give them after weaning?
 3. What is the best method of weaning?
 4. Shall I allow my pigs to run in a pasture, or shall I feed them in a pen?
 5. What crops shall I grow for my growing pigs?
 6. What special care will my pigs need in summer?
- VI. How shall I fatten my pigs for market?
 1. What records shall I keep that I may know how much the pork I am producing will cost?
 2. At what age will fattening for the market be most profitable?
 3. What is the most satisfactory ration I may feed for fattening?
 4. What is the most satisfactory method of feeding for maintenance during the winter?
 5. What special care will my pigs need in winter?
- VII. What kind of hog house shall I build?
 1. What factors shall I keep in mind in building a hog house?
 2. Can I afford an elaborate house?
 3. Can I make a plan for such a house as I need and build it?
- VIII. How can I prevent disease?
 1. Do I appreciate the importance of cleanliness and sanitation?
 2. Shall I give the pigs a chance to keep clean?
 3. Do I know how to prevent such common ailments as scours, worms, and lice?
 4. Do I know the nature of hog cholera, how to handle a case of infection and how to prevent such infection?
 5. Can I perform such simple operations as castration and extraction of teeth?

ALFALFA PROJECT STUDY OUTLINE.

INOCULATION AND USE OF LIME—A DEMONSTRATION PROJECT.

- I. Shall I undertake to demonstrate the production of alfalfa in this section?
 1. Has alfalfa been grown successfully in this section?
 2. Are there any limiting factors which can not be supplied at a profit?
 3. Is it evident that lime is one of the factors which limit the growing of alfalfa in this section?
 4. Can lime be secured at a price that will allow a profit?
 5. Is it evident that inoculation must be practiced for successful growth of the crop?
 6. Will it be worth while to demonstrate the value of lime and inoculation in alfalfa culture?
- II. Are my home farm conditions favorable to the growing of alfalfa?
 1. Is the soil of suitable texture and fertility?
 2. Is the soil of sufficient depth?
 3. Is the soil sufficiently well drained?
 4. Has previous cropping left it free of weeds which may have proven troublesome?
 5. Are there insect pests or diseases which may be beyond control?
- III. How shall I prepare my land for a stand of alfalfa?
 1. In what condition has the land been left by previous crops?
 2. Does the soil need fertilizing?
 3. When and how should barnyard manure be used for an alfalfa field?
 4. Can I afford to use commercial fertilizers on my alfalfa land; if so, how much, of what kind?
 5. What proof have I that my soil needs lime?
 6. What form of lime shall I use? ¹
 7. How much lime shall I use to the acre? ¹
 8. How shall I apply the commercial fertilizer and lime?
 9. When shall I plow? How deep?
 10. What other treatment will be necessary to make a fine seed bed?
- IV. What seed shall I plant?
 1. What variety of alfalfa will be best for this section?
 2. Where can I secure seed that will be best suited to this section?
 3. Have I planned to secure my seed sufficiently early?
 4. What precautions shall I take to be assured that the seed is free from noxious weeds?
 5. What would be a reasonable price for good seed?
 6. How shall I determine if the seed is of strong vitality?
- V. How shall I seed my plat?
 1. In what season shall I sow the seed?
 2. What evidence do I have that the soil needs inoculation?
 3. What method of inoculation shall I use?
 4. Where shall I obtain the culture or soil?
 5. What specific directions shall I follow in inoculation?
 6. What method of seeding shall I use?
 7. Shall I use a nurse crop?
 8. At what rate shall the seeding be done?

¹ The form of lime and the rate of application may be factors which are to be tested or demonstrated.

VI. What care will be essential the first season?

1. Shall I attempt to secure a crop of hay the first season?
2. What treatment will aid in the control of weeds?
3. At what height shall the young plants be cut?
4. Shall the clippings be removed?
5. Will there be any advantage in disking or in any other form of cultivation?
6. If the stand is uneven or thin will it pay to reseed?
7. In what condition should the stand of alfalfa be left for the winter?
8. Will it pay me to use a top-dressing of manure in the fall?

VII. How can I control the insect pests and diseases of alfalfa?

1. What insect pests and diseases of alfalfa are likely to prevail in this district?
2. What methods of prevention and control are most successful in practice?

ORCHARD PROJECT STUDY OUTLINE.

RENOVATION OF OLD ORCHARD—A DEMONSTRATION PROJECT.

I. Shall I undertake to renovate an orchard as my project?

1. Am I willing to undertake a project with little hope of immediate financial reward?
2. Will it not be worth while to gain practical experience in orchard management?
3. Will it not be worth while to demonstrate to the community the value of modern methods?
4. May I not make arrangements whereby I may share in the future profits which may result from my work?

II. Is the orchard worth renovating?

1. Are the trees too old?
2. Does vigorous growth indicate a good root system?
3. Is there a good stand of trees?
4. Are the trees of a variety known to be profitable?
5. Can I control all pests which may prevail?

III. How shall I prune the orchard?

1. Do I understand the principles underlying the pruning of fruit trees?
2. What tools will be required for my pruning work?
3. Can I use the pruning shears with dexterity?
4. Can I remove large limbs properly by using the saw?
5. What time of the year shall I do my pruning?
6. Will it be necessary to start new heads on the trees by "dehorning"?
7. Will it be necessary to remove a great many water sprouts, suckers, diseased and dead branches?
8. What treatment shall I give wounds left in removing large branches?
9. How shall I treat the rough trunks that they may not harbor pests?
10. What part shall pruning play later in keeping my trees in shape and as an aid toward producing fine fruit?

IV. How can I change the trees to a more desirable variety?

1. Do I understand the principles underlying budding and grafting?
2. Are my trees in such shape that top-working will be profitable?
3. What method of top-working shall I use?
4. Can I make a successful cleft graft?
5. Can I do ordinary budding with dexterity?
6. At what time of the year shall I graft or bud my trees?
7. What variety shall I use?

V. What fertilizing shall I give the orchard?

1. Do I understand the function of the fertilizing elements and their relation to tree growth?
2. If severe pruning has stimulated a vigorous growth, will the trees need nitrogen?
3. Will the application of fertilizers containing phosphoric acid and potash be beneficial?
4. What is the cheapest and best form in which I can apply the elements needed?
5. What are the objections to using barnyard and green manures the first year after the trees have been cut back severely?
6. When and how shall I apply fertilizers?

VI. How shall I cultivate the orchard?

1. What are the purposes of cultivation?
2. What are the advantages of cultivation over leaving the orchard in sod?
3. May it be advisable at any time to leave an orchard in sod?
4. What implements will be required for the cultivation of the orchard?
5. Am I able to do the plowing, harrowing, and cultivating which may be necessary?
6. When should cultivation cease?

VII. Shall I use a cover crop?

1. What is the distinction between a cover crop and the practice of intercropping?
2. What important purposes do cover crops serve?
3. What crops are suitable for the purpose?
4. What crop shall I use and how shall I manage it to secure maximum returns?

VIII. How can I control orchard pests?

1. What equipment will I need for spraying?
2. Can I make Bordeaux mixture and lime sulphur sprays and apply them in such a way as to control fungus diseases?
3. Can I use lead arsenate and Paris green effectively in the control of biting insects?
4. Can I control insects with sucking mouth parts, such as aphids and San José scale?
5. Do I know the life histories and habits of the insects I must control?
6. What may I do to supplement spraying in the control of orchard pests?
7. What may I do to get my neighbors to cooperate with me in the control of orchard pests?
8. Will it pay me to buy a spraying outfit, or will it be more profitable to hire the spraying done?

IX. Shall I thin my fruit?

1. What are the advantages claimed for the practice?
2. What objections are there against it?
3. Do I understand the details of thinning that I may practice it efficiently?

X. How shall I harvest my crop?

1. What equipment will I need for picking?
2. When is the fruit ready to pick?
3. Do I understand the details of picking that I may practice it efficiently?
4. If I need help in picking, can I manage the pickers to secure the best results?

XI. How shall I market my crop?

1. Shall I store my fruit or sell it directly from the orchard?
2. What preparations must I make for grading and packing?
3. What kind of package shall I use?
4. What system of grading and packing shall I follow?
5. Do I understand the details of grading and packing that I may do it myself or supervise it efficiently?
6. What plans must I make for marketing that I may get maximum returns?
7. What am I going to do with the fruit that does not grade up to standard?

POULTRY PROJECT STUDY OUTLINE.

DEVELOPING A FARM FLOCK—AN IMPROVEMENT PROJECT.

I. Shall I undertake the improvement of a flock of fowls as my project?

1. Is the flock of fowls at home in need of improvement?
2. Can I make arrangement to take hold of the flock on my own account?
3. Have I sufficient interest in fowls to enjoy the work?

II. What shall be my aim in the improvement of the home flock?

1. Shall I make a specialty of eggs for the market?
2. Shall I work toward special production of market poultry?
3. Shall I look forward to producing fowls for breeding and eggs for hatching?
4. Shall I increase the value of the flock for general purposes?

III. What breed shall I select?

1. What proof do I have that pure-bred fowls are superior to mongrels?
2. What breed is best adapted to my aim?
3. Shall I attempt to handle more than one breed and variety?
4. What variety shall I select?

IV. How shall I get my start toward a well-bred flock?

1. Shall I secure eggs for hatching?
2. Shall I secure baby chicks?
3. Shall I secure a pen of matured breeding fowls?
4. Shall I replace the mongrel males with birds of good breeding?

V. How shall I select and mate my fowls for best results?

1. Why is selection important in breeding?
2. What points shall I consider in selecting fowls for my breeding pen?
3. Do I know the characteristics of the breed and variety I am breeding?
4. Why is vigor and strong constitution important in all breeds?
5. Why should the male bird be given special attention?
6. What do I know about trap nesting and its value in the improvement of fowls?
7. Of what age should the fowls of my breeding pen be?

VI. How may I secure a good hatch of chicks?

1. Are my breeding fowls in condition to produce eggs with strong, fertile germs?
2. Why should I give special care to eggs intended for hatching?
3. What may I accomplish by proper selection of eggs intended for hatching?
4. Shall I use an incubator or hatch with hens?
5. Do I know from experience that I can manage an incubator successfully?
6. Can I afford to risk my best eggs while I am learning to operate an incubator?
7. How shall I manage sitting hens to secure the best results?

VII. How may I raise the chicks successfully?

1. Shall I use a brooder or depend upon hens?
2. Shall I buy a brooder or attempt to make one myself?
3. What needs of little chicks require special attention?
4. What system of brooding meets these requirements and fits my needs best?
5. Do I understand the details of brooder management?
6. Do I understand the details of management of hen and chicks?
7. Have I provided for the prevention of disease and pests?
8. What shall be my method of feeding and managing the chicks after weaning?
9. Do I have a good ration for growing chicks?

VIII. How may I increase the production of first-class eggs for the market?

1. Are the hens of the laying flock of suitable age?
2. Are male birds allowed in the flock which is producing eggs for market?
3. Are the hens fed a ration suitable to egg production?
4. Do they obtain clean, fresh water, grit, oyster shell, and charcoal?
5. Are they housed comfortably?
6. Do they obtain sufficient exercise?
7. Are they kept free from pests and disease?
8. Are the eggs gathered often and kept clean?
9. Shall I grade my eggs and work toward supplying a special market?

IX. How may I market my surplus fowls at a profit?

1. Shall I market my surplus males as broilers or roasters?
2. At what age shall I sell my hens?
3. What is the best system for me to use in fattening my fowls?
4. What rations will be profitable for me to feed?
5. What method of killing and dressing shall I use?

X. How shall I improve my poultry house?

1. Do I understand the essential features of a good poultry house?
2. Does my present house embody these features?
3. Will it pay me to remodel the old house or build a new one?
4. Can I plan a house suitable for my purpose which will embody all essential features?
5. Can I afford to build such a house?
6. Can I build the house myself or will I have to hire it built?
7. Where shall it be located?
8. Have I provided for suitable yards and runs?
9. Will proper drainage, protection from wind, and shade be provided?

FARM HOME PROJECT STUDY OUTLINE.

ORNAMENTATION OF HOME GROUNDS—AN IMPROVEMENT PROJECT.

I. Shall I undertake the improvement of our home grounds as a project?

1. What improvement can I make?
2. Does the improvement involve a knowledge of landscape art?
3. Have I a knowledge of art and horticulture as a foundation for such an undertaking?
4. Do I have a liking for such work?

II. What existing factors must I consider in the plan of my work?

1. To what extent may I modify present conditions?
2. How much time and money will I have to spend?
3. How large is the area to be included?
4. What features of this climate must I consider?

- II. What existing factors must I consider in the plan of my work?—Continued.
5. What bearing will the kind of soil have upon my plans?
 6. What about the water supply and drainage?
 7. Why will it be necessary to consider the exposure?
 8. What are the peculiarities of the site which I must take into consideration?
 9. To what extent must I consider the architecture of the house and other buildings?
 10. To what extent will I be free to use my own judgment in making my plans and in carrying them out?
- III. What preliminary work should be done?
1. What cleaning up about the yard is to be done?
 2. Are there any unnecessary and unsightly outbuildings to be removed?
 3. What can be done by a careful use of paint?
- IV. What shall be the essential features of my plan?
1. Shall I work for temporary or permanent effects?
 2. Shall I use a natural or a formal style?
 3. What walks and drives are necessary?
 4. What area shall be planted to lawn?
 5. Where are trees to be planted?
 6. What use is to be made of vines?
 7. Will a wind break be necessary?
 8. What part are hedges to play in the plan?
 9. Where shall my flower beds be located?
 10. When my plan is worked out will it present a pleasing picture?
 11. Will it provide for convenience and comfort?
 12. Will its execution be within my means?
 13. How shall a map of my plans be drawn?
- V. How shall I prepare for planting?
1. What provision shall I make for irrigation and drainage?
 2. What grading will be necessary?
 3. What must be done to put the soil into proper condition?
 4. What is the best season for doing this preliminary work?
- VI. How about the planting of trees?
1. Can I plant trees properly with reasonable assurance that they will grow?
 2. What deciduous trees shall I plant?
 3. What evergreen trees shall I plant?
 4. Are there native trees which will serve my purpose?
 5. Where shall I secure my nursery stock?
 6. How large shall the trees be for planting?
- VII. How about the planting of shrubbery?
1. What hardy ornamentals will I need to carry out my plans?
 2. What shall I plant for hedges?
 3. Can I propagate any shrubbery for myself?
 4. Have I assurance that the shrubs I have selected will prove hardy and that they will grow under my conditions?
- VIII. What vines shall I plant?
1. What vines shall I plant around the house?
 2. What vines will be best for screens and fences?
 3. What annual vines shall I use for temporary effects?
- IX. How shall I establish a lawn?
1. When shall I plant my lawn?
 2. How shall I prepare the soil?

IX. How shall I establish a lawn?—Continued.

3. What fertilizer shall I use?
4. What seed shall I plant?
5. Do I understand how to take care of a lawn properly?

X. What about flowers?

1. What flowers shall I use for bedding purposes?
2. What hardy annuals are suited to my purpose?
3. What perennials shall I use in the borders?
4. What use shall I make of bulbs?
5. Does my selection of flowering plants provide for a succession of abundant bloom throughout the season?
6. Do I understand the requirements of the plants I have selected?
7. What methods of propagation are involved?
8. Will I need a hotbed or frames for the production of plants?
9. Can I make and manage a hotbed?

XI. Can I control prevalent pests?

1. Have I considered insect pests and disease in the selection of plants?
2. Can I control the common insects which may prove harmful?
3. Can I control common plant diseases which may prove troublesome?

Suggested projects.—It should be borne in mind that the project should be adapted to the student, the course he is taking, and the community in which he lives. The following list will undoubtedly suggest other projects which will be profitable:

PRODUCTION PROJECTS.

1. Field crop production: Growing one-half acre or more of a field crop suited to the district.
2. Vegetable production: Growing one-fourth acre or more of a truck crop suitable to the district.
3. Flower production: Growing one-tenth acre or more of flowers for the market.
4. Home garden: Taking charge of home vegetable or flower garden.
5. Fruit production: Taking charge of bearing trees, a berry patch, or vineyard, and marketing the product.
6. Orchard development: Starting an orchard.
7. Developing a field of alfalfa or other perennial forage crop.
8. Developing a meadow or pasture.
9. Animal production: Poultry, pork, beef, mutton, wool, veal, and dairy products.
10. Development of breeding animals.

DEMONSTRATION PROJECTS.

1. Trying out crops new to district.
2. Variety tests.
3. Rotation of crops.
4. Fertilizer tests.
5. Care and use of banyard manure.
6. Use of cover crops and green manures.
7. Value of seed selection.
8. Methods of seeding.
9. Methods of cultivation.
10. Methods of orchard management.
11. Methods of feeding.
12. Use of preventive serums, dipping and other methods of preventing animal diseases.

13. Control of insects and other animal pests.
14. Control of weeds.
15. Control of plant diseases.

IMPROVEMENT PROJECTS.

1. Improving the home grounds in whole or in part, such as planting trees or developing a lawn.
2. Improving the school grounds.
3. Improvement of flock of poultry or herd of larger animals.
4. Plant improvement. Developing new strains by methods of plant breeding.
5. Community surveys and other organized work leading to rural betterment.
6. Construction or remodeling of farm buildings.
7. Concrete construction, building of fences, and making improvements involving principles of farm mechanics.
8. Construction of farm home necessities and conveniences.
9. Drainage of farm land.
10. Road construction, terracing, and leveling.

MANAGEMENT PROJECTS.

1. Taking general management of a farm.
2. Keeping farm records.
3. Making farm surveys.
4. Replanning problems.
5. Managing an orchard.
6. Managing a dairy.
7. Managing a farm woodlot.
8. Managing a poultry plant.
9. Managing a breeding herd or flock.
10. Managing work animals.

SOME PROJECT PROBLEMS.

The home-project plan has not been used sufficiently long to have established a very definite order of procedure. Many phases of its application are still in process of development, some of them being yet in the experimental stage. The following problems are suggestive of some questions which are being given attention at this time by those most interested. The extent to which the plan is adopted will depend in great measure upon how well some of these problems may be solved.

Supervision of projects.—The success of the home project will depend to a great extent upon proper supervision. There are so many factors which will determine the time taken for supervision that no rule can be laid down as to the number of students one teacher should supervise. The number is limited, however, when compared with the number taken care of with the usual academic, classroom instruction. Project work when conducted properly is expensive. As summer supervision is most important, schools which can not afford to hire an instructor for the full year may well hesitate about adopting the plan. Adequate means of transportation should be provided for efficient supervision, which means another item of expense.

The teacher should not scatter his attention over too wide a range of projects. He may well center his efforts upon the leading industry

of the district or upon a phase of farming most needed. To aid the teacher in centering his efforts upon one or two kinds of projects, some schools have adopted the alternate plan of subjects and projects. If four years of agriculture are outlined, the first and third years' work is given one year and the second and fourth years' courses and projects are worked out the next.

Fitting projects to the course of study.—It has been found most satisfactory to make the project sufficiently extensive to correlate with one year's work. In States where the home project is the basis for the teaching of agriculture, there is a question as to whether the class work and study of agriculture shall grow out of the project or whether the project shall develop from the agricultural study. If it is decided to require a project of each agricultural student the question will arise, To what extent shall the regular class work be devoted to projects, and to what extent shall the student pursue an individual project study?

Giving credit for projects.—It is customary to require two hours of practical work in field or laboratory for one hour's credit. Shall credit for home-project work be given upon the same basis and allowance for this work be made in making up the schedules? The question may arise as to whether one type of work is not worth more credit than another. To what extent shall quality of work and results obtained be considered in giving credit? If extra time is put in on projects shall extra credit be given? Shall the student's record of time be used in awarding credit, or labor-requirement tables be worked for different farm operations? The problem of giving school credit for home work is being given attention so it may soon be possible to answer these questions and others which may arise in a more satisfactory way than at present.

Contests, prizes, and awards.—In the elementary school most of the home work in agriculture has been in connection with club work in which the contest idea is a strong feature. Some teachers in the high school have linked their home-project work with the organized club work. The question arises as to just how far the high school teacher should use the contest idea, and to what extent prizes and awards other than regular school credit shall be given as incentives in regular projects.

To what extent shall projects yield a profit?—Boys in the high school have reached an age where they are beginning to consider values in terms of dollars and cents. One of the chief educational values of the home-project plan lies in the fact that through it the boy may be taught the value of a dollar. If this fact is considered, the question may well be asked, Is not the production project the most profitable from an educational point of view? While making a profit may be the chief aim of a production project it may enter into other projects

as well. If a student carries on a successful project of any other type he should have hope of some reward in addition to the school credit he may gain. It may be better to assign at the beginning of the work a project where there is hope of immediate profit. As the student grows older he will appreciate better the fact that many of the profits in farming are not gained immediately.

Securing cooperation of parents.—It is not always an easy matter to get the parents to agree to let the boy receive the profits from his project. Neither will they at all times agree to let the student carry on a project according to the plans he may work out in connection with his course of study. In fact, the securing of the cooperation of the parents is one of the most difficult problems in certain sections. As a rule, the teacher will accomplish more by working quietly to win the confidence and good will of the parents and patrons than he will by making arbitrary rules. A campaign of education among parents and an extension of aid from the agricultural department of the school are coordinate in some sections with the project work. The agricultural instructors are required to carry on extension work among adults while they are supervising the projects of students.

Substitutes for home projects.—In many schools there will be students interested in the study of agriculture who do not live upon farms, or who are not able to carry out a project which will fit in well with their course of study. It is possible that practical work may be secured for such students that will accomplish the same results as a home project. If a boy is taking a course in dairying and can not take care of cows at home, it may be possible that he can secure work upon a dairy farm. If his work is such that it will fit in with a project plan there should be no objections to giving him credit for the work. Likewise, a student of horticulture may work in a commercial orchard or a market garden and get practical experience which will be worthy of credit if it is connected with the work of the school.

Preparation of teachers.—Possibly the factor which limits most the teaching of practical agriculture is the lack of training among teachers for this kind of teaching. Teachers who are prepared to succeed in the supervision of home projects are such men as are in demand for various phases of extension work. As the demand for such men at present is greater than the supply, comparatively high salaries must be paid. It is worth while for teachers to make an extra effort toward giving practical training to their students, if considered only from the selfish view of getting experience in a kind of training which is in strong demand. In several of the agricultural colleges the departments of agricultural education are now giving special attention to practical training for project work.

UNITED STATES DEPARTMENT OF AGRICULTURE



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LOGAN WALLER PAGE, Director

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PROFESSIONAL PAPER

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METHODS FOR THE DETERMINATION OF THE PHYSICAL PROPERTIES OF ROAD-BUILDING ROCK.

By FRANK H. JACKSON, Jr., *Assistant Testing Engineer.*

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INTRODUCTION.

This bulletin is a partial revision of a former bulletin by Albert T. Goldbeck and Frank H. Jackson, jr., issued June 10, 1912.¹ The first bulletin dealt not only with the method of testing rock for road building, but also gave the results of laboratory tests obtained by the office on all rock samples received to July 1, 1911, together with the interpretation of those tests. It appears advisable to present complete results of tests by the office at rather frequent intervals, so that additional data may be promptly available for the general use of highway engineers. The present bulletin has thus been limited to a description of methods employed by this office for testing rock for road building, and is intended to serve as a more or less permanent laboratory manual for those who have occasion to make such tests.

Although the methods of determining the physical properties of rock used in macadam road construction have remained essentially the same since the publication of Bulletin 44, experience gained

¹ Office of Public Roads Bulletin No. 44, The Physical Testing of Rock for Road Building.

since that time in the actual routine of testing has shown the necessity of strictly adhering to many apparently minor details the importance of which was not formerly fully emphasized. Particular stress has been laid upon these details, in order that others engaged in, or about to engage in, this line of work may, with the least amount of preliminary experimentation, obtain results of practical value.

The first systematic attempts to determine the value of rock for road-building purposes by means of laboratory tests were made in France, where in 1878 a road-material laboratory was founded in the French School of Bridges and Roads at Paris. Here the Deval abrasion test was adopted, and this test with slight modification has been accepted as standard throughout the United States. The test is named from its inventor and was first used in connection with contract work in the city of Paris. Many valuable data were also collected in this laboratory on the hardness and toughness of rock, and tests for these properties were developed which were, in principle, the same as those in use to-day.

Outside of France very little work was done in road-material testing in either Europe or America until 1893, when the Massachusetts Highway Commission established a laboratory in the Lawrence Scientific School of Harvard University, under the direction of Logan Waller Page. The Deval abrasion test was adopted and a test to determine the binding power of rock dust was developed by Mr. Page in this laboratory.

In December, 1900, the United States Government established a laboratory in the Bureau of Chemistry of the Department of Agriculture, under the direction of Mr. Page. This laboratory became in 1905 a part of the Division of Tests of the newly organized Federal Office of Public Roads. On July 1, 1915, during a general reorganization, it was placed in the Division of Road Material Tests and Research of the new Office of Public Roads and Rural Engineering. The recent general interest in road improvement has also resulted in the establishment of many laboratories in technical and scientific institutions both in this country and abroad, as well as in the various State highway commissions.

PHYSICAL PROPERTIES OF ROAD-BUILDING ROCK.

The suitability of rock for use in highway construction is largely determined in the laboratory by tests of certain physical properties which have a direct bearing upon the behavior of the rock under service conditions. In the case of rock intended for use in water-bound macadam construction, experience has shown that the qualities most essential to success are those of hardness, toughness, and binding power. These properties may be briefly defined as follows:

Hardness is the property a rock should possess in order to successfully resist the abrasive action of traffic, especially iron-tired vehicles, which tend to grind to dust the individual fragments of rock forming the wearing course of a macadam road.

Toughness is the property a rock should possess to successfully resist fracture under the impact of traffic.

Binding power, or *cementing value*, as it is more frequently called, is the ability which the dust of a rock should possess or develop by contact with water, so as to bind or cement the larger rock fragments together and prevent their displacement under the shearing action of traffic. This property is especially valuable in water-bound macadam construction, since it is depended upon to maintain the integrity of the wearing course as the road surface is worn off by traffic.

PHYSICAL TESTS OF ROAD MATERIALS.

A description of the various tests employed to determine to what extent a rock possesses the qualities outlined above, in addition to certain other properties of interest to highway engineers, is given in the following pages.

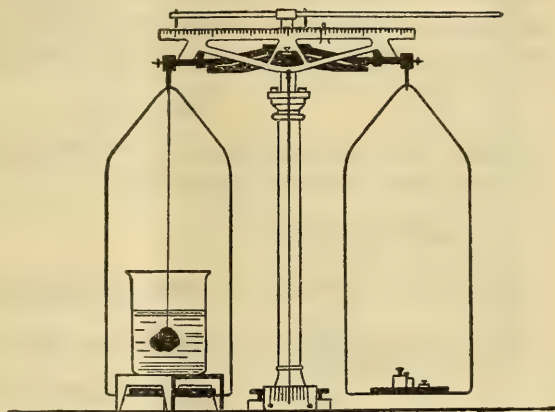


FIG. 1.—Displacement method of determining specific gravity.

SPECIFIC GRAVITY—WEIGHT PER CUBIC FOOT—WATER ABSORPTION.

OBJECT.

To determine the weight of a solid cubic foot of the material and the number of pounds of water which will be absorbed by a cubic foot in 96 hours.

EQUIPMENT.

Beam balance weighing accurately to 0.01 gram and provided with suitable means for suspending the material in water while weighing. (See fig. 1.)

Drying oven.

Desiccator and calcium chloride.

Thermometer.

METHOD.

A fragment of the rock weighing approximately 10 grams and representing as nearly as possible an average of the entire sample is dried for several hours to constant weight in a hot-air bath, cooled

in a desiccator, weighed in air, weighed in water at 25° C., immersed in water for 96 hours, and again weighed in water. The specimen should be suspended by means of a thin silk thread from the hook on one of the beam supports about 1½ inches above the pan when weighing. When weighed immersed in water, the small amount of water absorbed by the thread is neglected. It is essential that the first weight in water be obtained as quickly as possible in order to secure the correct specific gravity of the material. This is especially true of very porous rock. In practice it is customary to do this by first obtaining the approximate weight of a trial specimen, both in air and in water, and of the true test specimen in air. The correct weight of the true specimen in water is next calculated as nearly as possible by proportion. This weight is then placed on the scale pan previous to the immersion of the true specimen in water.

COMPUTATIONS.

Calling the weight in air a , the weight in water b , and the weight in water after 96 hours' immersion c ,

$$\text{the specific gravity} = \frac{a}{a-b};$$

$$\text{the weight in pounds per cubic foot then} = \frac{a}{a-b} \times 62.37 \text{ pounds};$$

$$\text{the water absorption in pounds per cubic foot} = \frac{c-b}{a-b} \times 62.37.$$

VALUE OF TESTS.

The weight per cubic foot is of value in estimating the weight of any given volume, as a cubic yard or carload, of the crushed stone. Thus, assuming 50 per cent voids in the crushed material,

$$\text{the weight in pounds per cubic yard loose approximately} = \frac{\text{Wt. per solid cu. ft.}}{2} \times 27.$$

The absorption test is of value in judging the probable lasting qualities of the rock under the action of frost, since the presence of frost in the stone is likely to promote weakness or even disintegration. It may also be of value in estimating the probable error due to absorption in the weight of a quantity of stone exposed for some time to the weather.

DEVAL ABRASION TEST.

OBJECT.

To determine the per cent of wear and the French coefficient of wear.

EQUIPMENT.

Deval abrasion machine.

This machine (see fig. 2) consists essentially of the pulley A , or worm gear and motor as at present used, driving the shaft BB upon which are mounted the four cast-iron cylinders $CCCC$ in such a way

that the axes of the cylinders are inclined at an angle of 30° with the axis of rotation. These cylinders are 20 cm. in diameter and 34 cm. in depth inside. The shaft is set in the three bearings *DDD* and carries at one end a revolution counter which is not shown in the cut.

Balance weighing to 5 kilograms and sensitive to 0.5 gram.

This balance should preferably be equipped with a supplementary scale pan, measuring 10 inches in diameter and 2 inches high, and a suitable counterweight. This will make it possible to weigh the entire sample in one operation.

50-pound anvil.

Stone hammers.

Several 3-quart enameled iron pans.

Sieve.

The sieve should preferably be brass rimmed and reinforced in order to withstand heavy usage, about 16 inches in diameter, with square mesh of one-sixteenth (0.0625) inch clear opening.

Drying oven.

METHOD.

The material is broken into pieces as nearly of the same size and shape as practicable, so that approximately 50 pieces shall weigh, after thorough drying, to within 1 gram of 5,000 grams. In no case should the number of pieces exceed 60 or be less than 40. Care should be taken to use only freshly broken fragments, as pieces with rounded edges greatly affect the results. Although the size of the individual pieces composing a sample varies theoretically

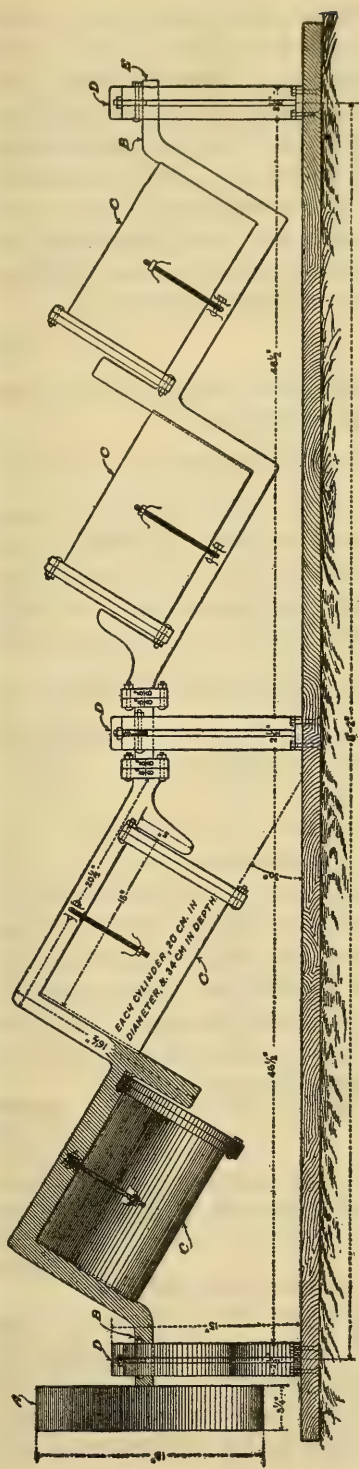


FIG. 2.—Abrasion machine—Deval type (front view).

with its specific gravity, in practice the pieces may be so broken as to average from 2 to 2½ inches in diameter with the assurance of obtaining a properly sized sample. After weighing, the sample is placed in one of the cylinders of the Deval machine, the cover bolted on, and the machine given 10,000 revolutions at the rate of 30 per minute. At the conclusion of the test the sample is screened on the one-sixteenth inch sieve, the material retained thoroughly washed free from dust, dried in the oven, and again weighed. The difference between this weight and that first obtained represents the wear as determined by test.

COMPUTATIONS.

The initial weight in every case being 5,000 grams, and calling the final weight a ,

$$\text{then the per cent of wear} = \frac{5,000 - a}{5,000} \times 100.$$

The French coefficient standard is based on the theory that a rock of standard excellence does not lose more than 100 grams under one-sixteenth inch in size during a test. This is equivalent to 20 grams per kilogram of rock used, or 2 per cent of the original weight. Assuming, then, a coefficient of 20 for such a rock, the French coefficient of wear for any material $= 20 \times \frac{20}{W} = \frac{400}{W} = \frac{40}{\text{per cent of wear}}$ where W equals the loss in weight under one-sixteenth inch in size per kilogram of rock used.

VALUE OF THE TEST.

In this test the sample is thrown the length of the cylinder twice in each revolution so that the individual stones grind against each other, as well as against the sides of the cylinders. The rock may likewise be broken by the impact, so that the test may be considered as one not only for hardness but for toughness. Values of the per cent of wear run from as low as 1 in certain rare cases to as high as 30 or even 40 for some sandstones and limestones.

This test was standardized in 1908 by the American Society for Testing Materials.

HARDNESS TEST.

OBJECT.

To determine the resistance which a rock offers to the displacement of its surface particles by friction.

EQUIPMENT.

Diamond core drill.

The core drill is shown in figure 3, and consists essentially of the steel core tube A , measuring 1 inch inside diameter and 4 inches in length, fastened at its upper end to the hollow shank B . This is held in an ordinary drill press, equipped with a special hollow spindle. Running water is introduced in the upper end of the spindle from a

one-fourth-inch pipe, while the drill is held in its lower end by means of a headless set screw instead of the usual drift hole. In this way water may be carried in a very simple and convenient manner to the inside of the revolving drill. This method of supplying water to the drill has proved simpler and more satisfactory than the scheme described in Bulletin 44, in which the water is introduced at the side through a stationary brass ring.

The Tobin bronze drill crown *C*, carrying the diamond points, is soldered to the lower end of the steel core tube *A* as shown in the cut. The crown should measure about one-eighth of an inch thick across its lower face, should be about three-sixteenths of an inch thick, and show a slight taper in its outer side, to allow clearance when cutting. Eight or ten holes are drilled in the lower face of the crown, of such size that the diamonds will wedge firmly into them, until nearly flush with the surface.

Black diamonds or carbons.

The diamonds used in the drills and saws should be dense, regular in shape, and should range in size from one-sixteenth of an inch to three thirty-seconds of an inch in diameter. No flat, scaly, or porous diamonds should be used. Diamonds suitable for this work will usually weigh about one-tenth of a carat (0.02 gram) each.

Diamond saw.

A cut of the diamond saw is shown at *A*, figure 4. The saw proper is made of Russia iron and consists of a flat disk 8 inches in diameter and 0.03 inch thick. It is made as follows:

The saw is firmly clamped between two circular wooden blocks $7\frac{1}{4}$ inches in diameter, leaving one-eighth of an inch projecting all

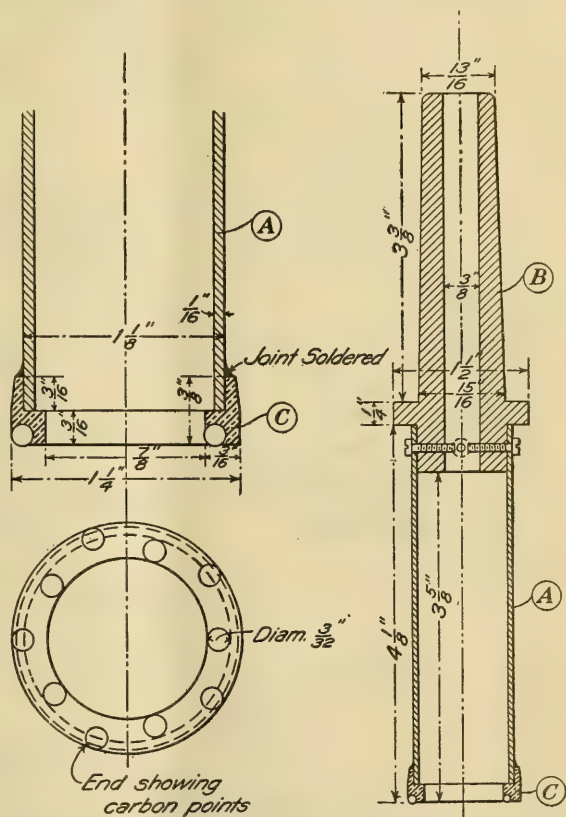


FIG. 3.—Diamond core drill.

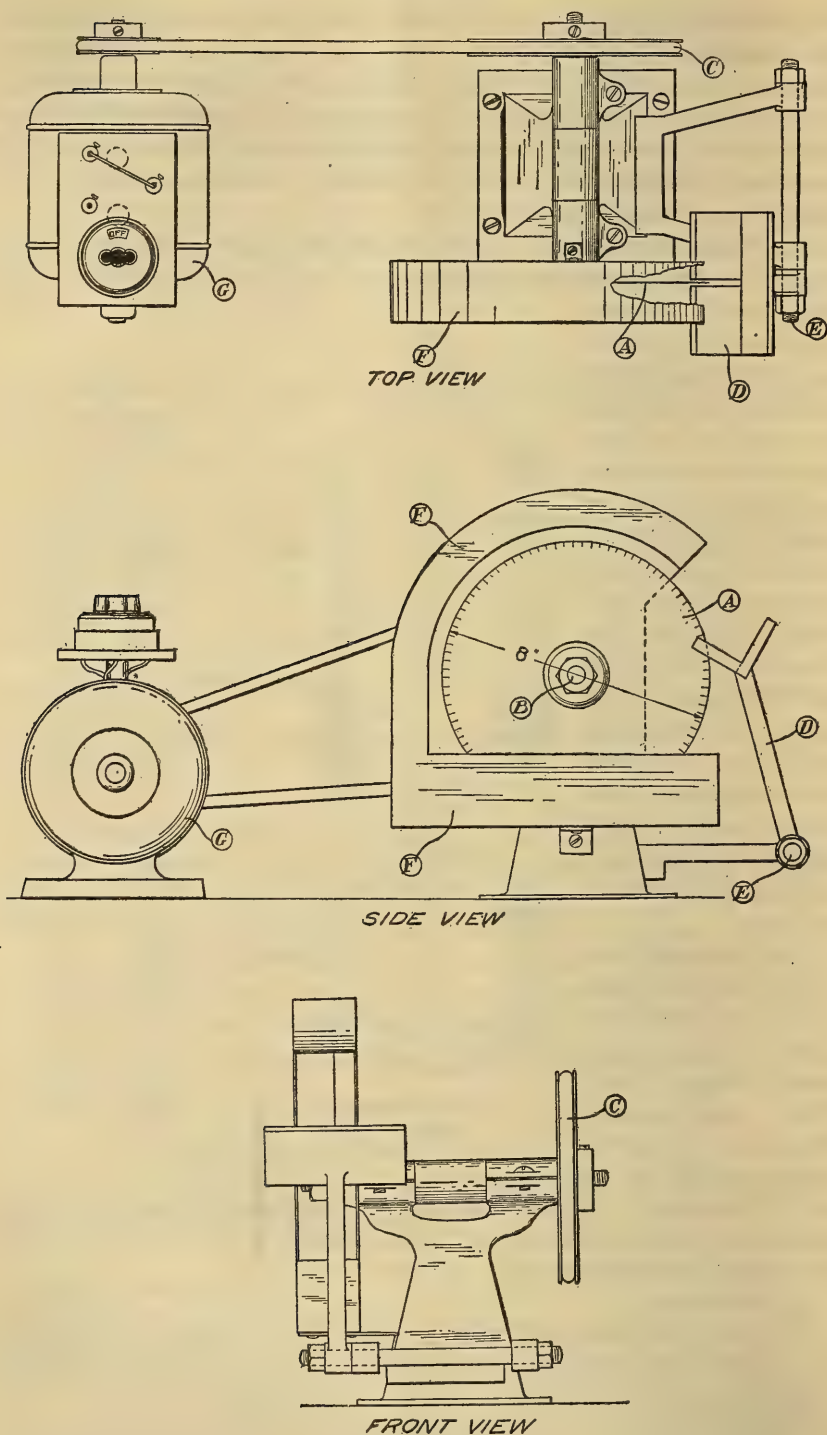


FIG. 4.—Diamond saw.

around. By means of a small one-fourth-inch steel chisel radial cuts are made in the saw one-eighth of an inch apart and one-eighth of an inch deep. The spaces between the cuts are then slightly opened by bending the projections alternately to the right and left. A mixture of vaseline and fine diamond fragments is inserted in each cut. All of the cuts are then closed with a pair of pincers and hammered down to the original thickness of the saw, thus driving the diamond dust into the metal. The diamonds are not ground to a powder, but are merely broken up into very fine fragments. A very small amount

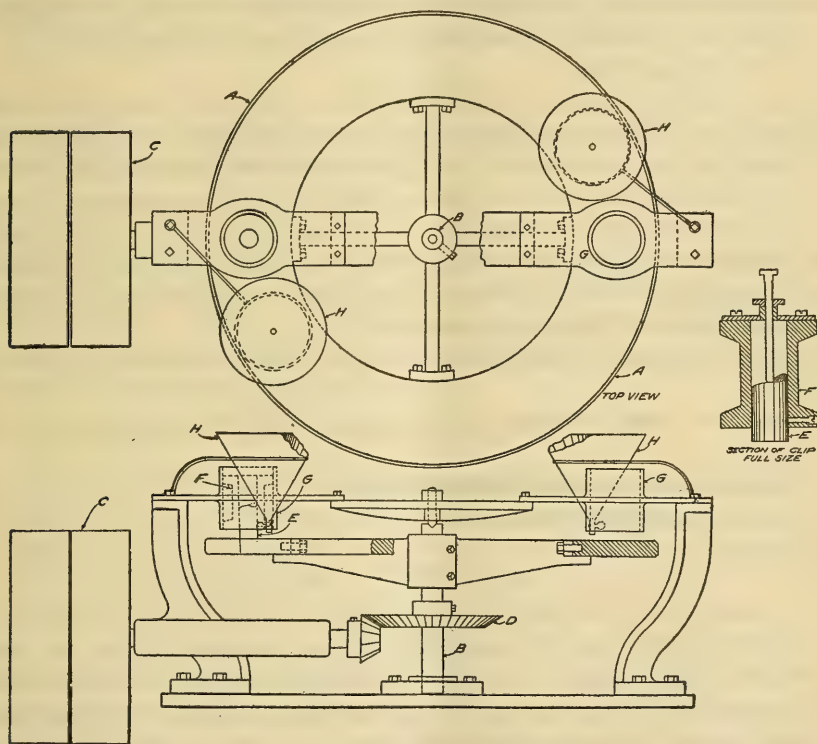


FIG. 5.—Details of Dorry hardness machine.

of the mixture taken on the end of a toothpick is sufficient for each cut. Just enough vaseline is used to enable one to pick up the diamonds.

The saw is mounted on a spindle (B, fig. 4) driven by the pulley (C) at 600 revolutions per minute from a motor (G). The specimen to be cut is held in the V block (D), which is mounted on a swinging arm pivoted as at (E). The lower end of the saw runs continuously in water contained in the galvanized-iron pan (FF).

Dorry hardness machine.

The Dorry machine in use at the present time is a modification of the original French machine, and consists fundamentally of a circular steel disk (A, fig. 5), which is revolved in a horizontal plane by means

of the bevel gear (*D*), driven by the pulley (*C*). At *F* is shown a brass grip for holding the test specimen. The grip carrying the specimen is held in a vertical position over the steel disk by inserting it in the sleeve (*G*), which is of such size as to form a sliding fit allowing free vertical but no sidewise movement of the grip. The abrasive, crushed quartz is fed onto the disk through the funnel (*H*), the lower end of which should form an opening one-fourth of an inch in diameter. The sleeve (*G*) is so placed that the center of the grip, when in position, will be 26 cm. from the center of rotation of the disk. A revolution counter is mounted as at (*B*). A galvanized-iron hopper, not shown, is fitted under the disk to receive and carry away the used sand.

Crushed quartz sand.

The sand used as the abrasive agent is a crushed quartz, screened to pass a standard sieve having 30 meshes per linear inch and to be retained on a standard sieve having 40 meshes per linear inch. Since it is almost impossible to obtain such a sand commercially, it is customary to specify a sand not more than 5 per cent of which will be retained on a No. 30 sieve and not more than 25 per cent of which will pass a No. 40 sieve. Sand known to the trade as No. 2½ quartz will usually fulfill these requirements.

Standard sieve 16 inches in diameter, with 30 meshes per linear inch.

Standard sieve 16 inches in diameter, with 40 meshes per linear inch.

Balance, same as used in abrasion test.

Several small metal washers.

METHOD.

A core 25 mm. in diameter and about 10 cm. long is cut with the diamond drill from the specimen to be examined. To use the diamond drill properly, so as to avoid undue wear, requires great care and considerable experience. It is convenient to mount the specimen under test on the table of the drill press by means of a bag filled with sand, which forms a cushion for the irregular, projecting edges of the rock. Very small specimens may be mounted in plaster of Paris. The core should in every case be drilled perpendicular to the bedding plane of the rock, using the hand feed of the drill press only, with just enough pressure to cut. Should the core be not cut entirely through the specimen it may be removed by inserting the end of a small screw driver into the cut and using it as a lever to break the core away from the bottom. After thoroughly drying, the specimen is inserted in the brass grip of the Dorry machine, leaving about 1 inch projecting from the lower end. The grip is then inserted in the sleeve so that the lower end of the specimen rests on the steel disk. The funnel is filled with sand and the machine run until the lower end of the specimen has been worn down to the plane of the disk. The

grip carrying the specimen is then removed, brushed free from dust, and accurately weighed. By means of the small metal washers, any one or more of which may be slipped over the projecting rod of the grip, the initial weight should be adjusted to exactly 1,250 grams. The grip is then replaced in the same position as before and the machine given 1,000 revolutions at the rate of 30 per minute, after which it is again weighed. The test should be repeated with the specimens reversed, in order to obtain the average hardness of the two ends.

The one-fourth inch opening in the funnel of the hardness machine will allow 18.5 pounds of sand to pass through during a test.

COMPUTATIONS.

Calling the initial weight of grip plus specimen a and the final weight after 1,000 revolutions b ,

$$\text{the coefficient of hardness} = 20 - \frac{(a-b)}{3}.$$

The coefficient 20 was chosen as the standard of comparison to give about the same range of values as those obtained by the Deval abrasion test. The loss in weight is divided by 3 in order to avoid negative coefficients, since it was found that a specimen might lose as high as 60 grams in a single test.

VALUE OF TEST.

The test is of value in determining the resistance of a rock to the grinding action of traffic. The coefficient of hardness for various types of rock will run from 19.7 for the hardest varieties of quartzite to 0 for very soft limestones and sandstones.

TOUGHNESS TEST.

OBJECT.

To determine the resistance which the material offers to fracture due to impact.

EQUIPMENT.

Diamond core drill (same as used in hardness test).

Diamond saw (same as used in hardness test).

Grinding lap.

The grinding lap used for preparing specimens for the toughness test is shown in figure 6. It is 9 inches in diameter and is driven by means of a small electric motor at a speed of 400 revolutions per minute. Finely powdered carborundum is used as an abrasive agent.

No. 120 carborundum.

Page impact machine.

In the Page impact machine (fig. 7), a 2-kilogram hammer (N) is guided by two vertical rods (J). The upper end of the hammer

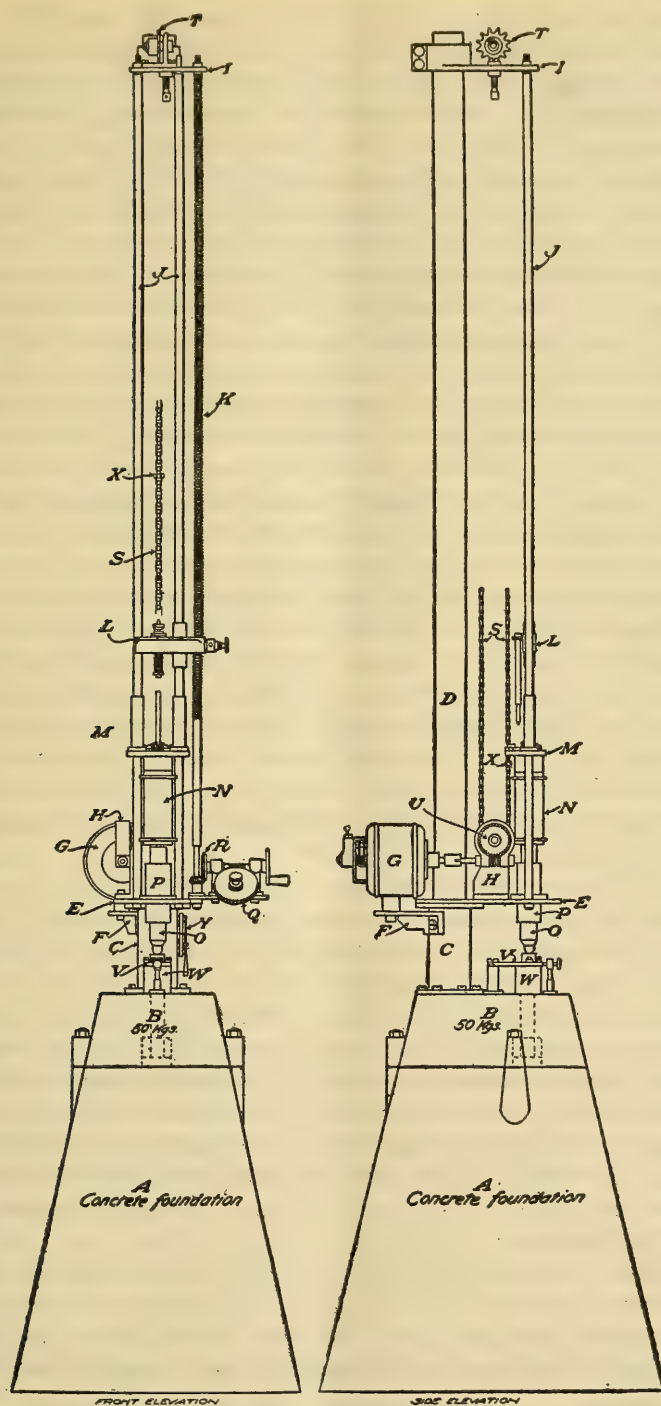


FIG. 7.—Details of Page impact testing machine.

are attached to castings at the top (*I*) near the base (*H*) of the machine. The lower sprocket wheel is directly connected by a worm gear to an electric motor (*G*). The sprocket chain is provided with four small lugs (*X*), which, when the chain is being driven by the motor, engage a spring bolt attachment which projects inward on either side of the slot on the crosshead (*M*). This raises the crosshead until tripped by a rod projecting downward from an upper crosshead (*L*). When this takes place the crosshead (*M*) which holds the electromagnet falls until it comes in contact with the hammer (*N*). The electromagnet is supplied with current from the circuit in series with an ordinary electric lamp which not only serves to cut the voltage in the line but acts as a pilot lamp as well. This current is conveyed through two small conducting rods running parallel to the guide rods, both of which are insulated from the rest of the machine. The current passes from one of these conductor rods through a small carbon brush to a make-and-break attachment on the upper crosshead (*L*), thence down one of the guide rods, through the electromagnet, and back to the other conductor rod.

When the crosshead (*M*) is raised by the lugs on the sprocket chain and the current turned on the magnet the hammer is lifted until the crosshead (*M*) comes in contact with the make-and-break on the crosshead (*L*) and thus releases the hammer, which falls, striking a plunger (*O*). The plunger is made of armor-piercing steel, with the maximum temper at its lower end, which is spherical in shape. The upper surface of the test piece, which rests on a counter anvil (*W*) of hard steel, is in direct contact with and tangent to the spherical end of the plunger at its center point.

It will be observed that the blow as delivered through a spherical-end plunger approximates as nearly as practicable the blows of traffic. Besides this it has the further advantage of not requiring great exactness in getting the two bearing surfaces of the test piece parallel, as the entire load is applied at one point of the upper surface.

The upper crosshead (*L*) is raised through any desired height by means of the long revolving screw (*K*), which is geared at its lower end to a dial (*Q*), on which the height of the make-and-break attachment, and therefore the height of the hammer drop, may be read directly. By means of the revolving dial and screw the height of the crosshead may be adjusted, by very close approximation, to within 1 millimeter.

In order to prevent the crosshead (*M*) which holds the electromagnet from striking too hard a blow on the hammer when falling, a dashpot was first used, but it has been found that a few drops of cylinder oil on the lower end of the guide rods completely eliminated this difficulty.

METHOD.

A core of the rock which is to be tested is first drilled, as described under the hardness test. In many cases the core which has already been subjected to the hardness test may be used. A cylinder a little over 25 millimeters long is next cut from the rock core by means of the diamond saw. The ends are then ground plane on the grinding lap, making the length of the specimen when completed exactly 25 millimeters. Although it is not necessary that the two ends of the specimen be exactly parallel, one surface at least should be as nearly perpendicular to the axis of the cylinder as it is possible to make it. After drying, the specimen is placed on the anvil (*W*) of the Page impact machine, taking extreme care that when in position the specimen rests with a perfect bearing on the anvil and that the spherical end of the plunger touches the specimen exactly in the center of its upper surface. The small thumbscrew used for separating the clips which hold the specimen in place should be so adjusted that the clips hold the specimen firmly without any undue pressure on the spring. Attention to these details is very important if accurate results are to be obtained. When the specimen is in position the current is turned on the magnet and the upper crosshead is lowered until the rod projecting from it just comes in contact with the rod projecting up from the lower crosshead (*M*). This occurs at the instant the pilot lamp, in series with the magnet circuit, flashes out. The dial (*Q*) is then adjusted to (*O*), the upper crosshead raised 1 centimeter, and the motor started. After each blow the fall of the hammer is increased 1 centimeter until failure of the test piece occurs.

COMPUTATIONS.

The height in centimeters of the blow at failure is recorded as the toughness of the material. The average of two determinations is taken.

VALUE OF TEST.

This test is useful in determining the comparative resistance of rock to the impact of traffic produced by the action of horses' hoofs, etc., on the stones forming the wearing course of a macadam road. Toughness in rock varies through a wide range of values from as low as 2 or 3 in the case of some limestones and sandstones to as high as 60 in rare instances.

This test was standardized in 1908 by the American Society for Testing Materials.

CEMENTING VALUE TEST.

OBJECT.

To determine the ability which the rock powder, when wet, possesses of binding the larger fragments together.

EQUIPMENT.

Small jaw crusher.

Balance (same as used in abrasion test).

100 c. c. graduate.

Several 1-pint jars, with metal screw caps.

Ball mill.

The ball mill shown in figure 8 consists essentially of the cast-iron casing (*AB*), split into the two unequal segments (*A* and *B*). It revolves in a vertical plane on the shaft (*CC*) bearing in the pillow blocks (*DD*) and driven by the pulley (*E*). The steel shot used for grinding measure 5 inches in diameter and weigh 20 pounds each. Two shot are used in each mill.

Briquette-forming machine.

This machine is shown in figure 9 and consists fundamentally of a hydraulic cylinder (*A*) supporting an iron platform (*B*) through the piston rod (*C*). The cylindrical metal die (*D*) is provided with a closely fitting plug (*E*) supported by guide rods (*KK*). The supply pipe shown in the cut admits water to the cylinder. The lever arm (*G*) is provided with an adjustable weight (*H*) consisting of a hollow cylinder partially filled with shot. Details of the metal die are shown in figure 10, in which a small metal stand (*A'*) shaped in the form of a half circle is used in removing the compressed material.

Small balance weighing to 100 grams and sensitive to 0.1 gram.

Millimeter scale.

Drying oven.

The oven should be equipped with a thermometer and regulating device for maintaining a constant temperature of 100° C. for several hours.

Desiccator and calcium chloride.

Shellac dissolved in alcohol.

Page impact machine for testing cementing value.

The machine as shown in figure 11 consists essentially of the motor (*A*) driving the cam shaft (*E*) by means of a worm gear at the rate of 60 revolutions per minute. The plunger (*H*), weighing one-half kilogram, is held in position on the briquette (*I*) by means of two spiral springs, one on each side of the sleeve in which the plunger slides. The lever (*L*) is pivoted on the plunger through a slot cut in the sleeve. It carries a brass pencil at one end, while the other is provided with means for adjusting the height of the pencil with reference to the drum (*M*). The hammer (*G*), weighing 1 kilogram, is raised by the pin (*F*) which slides upon the face of the cam (*E*). The pin is provided with a thumbscrew and locknut (*F*) for adjusting and maintaining its vertical position. The cam (*E*) is also provided with means for imparting at each revolution a slight motion to the drum (*M*), so that the drum makes one complete revolution for each 100 blows of the hammer.

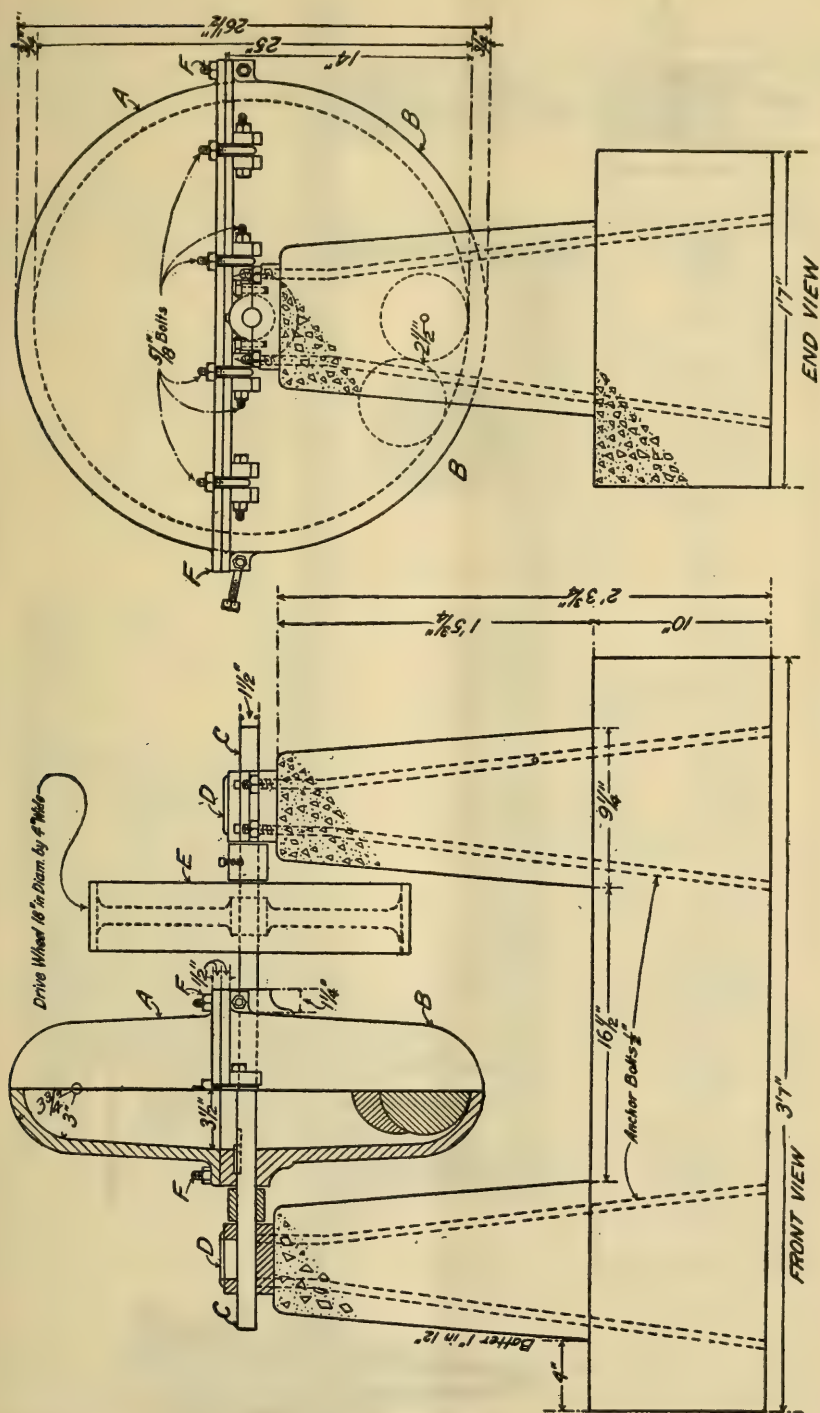


FIG. 8.—Details of ball mill.

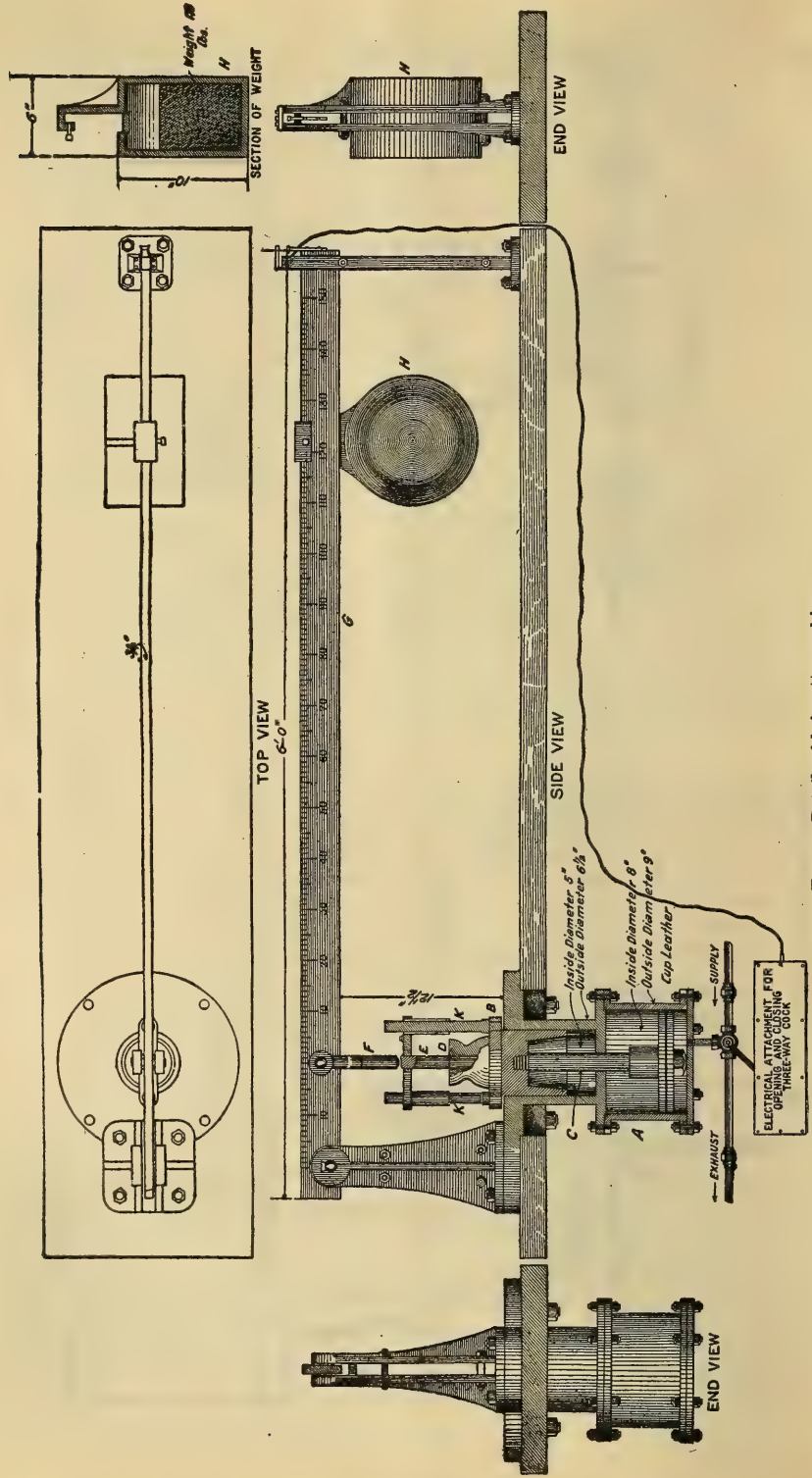


FIG. 9.—Details of briquette machine.

Sensitized paper.

The paper used for recording the number of blows delivered by the hammer of the impact machine measures 8 by $2\frac{1}{4}$ inches in size and is sensitized on one side to take the impression of a brass point.

METHOD.

A 500-gram sample of the material to be tested is crushed to pea size and placed in the ball mill together with 18 per cent (90 c. c.) of water. After 5,000 revolutions of the mill, at the rate of 30 per min-

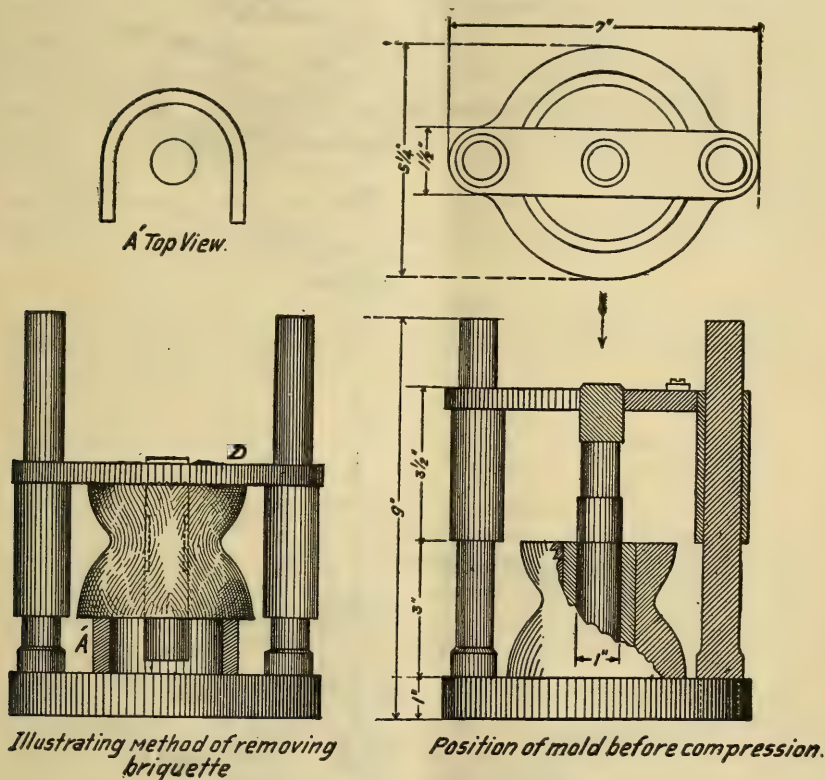


FIG. 10.—Details of briquette mold.

ute, the resulting dough is removed and molded into briquettes 25 mm. in diameter and 25 mm. high. The dough should never be allowed to stand in the open air after grinding and previous to molding, but should be tightly sealed in a fruit jar. Even when sealed, however, the dough should not be allowed to stand more than two or three hours before molding into briquettes. In order to obtain briquettes of the proper height, a trial specimen should be made as follows: 28 grams of the material is weighed and placed in the die, the plunger inserted, and the whole placed upon the platform of the briquetting machine. Water is admitted to the cylinder until the

pressure is just sufficient to raise the lever arm. This will take about 30 seconds. The weight on the lever arm should be so adjusted that there will be a maximum pressure on the briquette of 132 kilograms

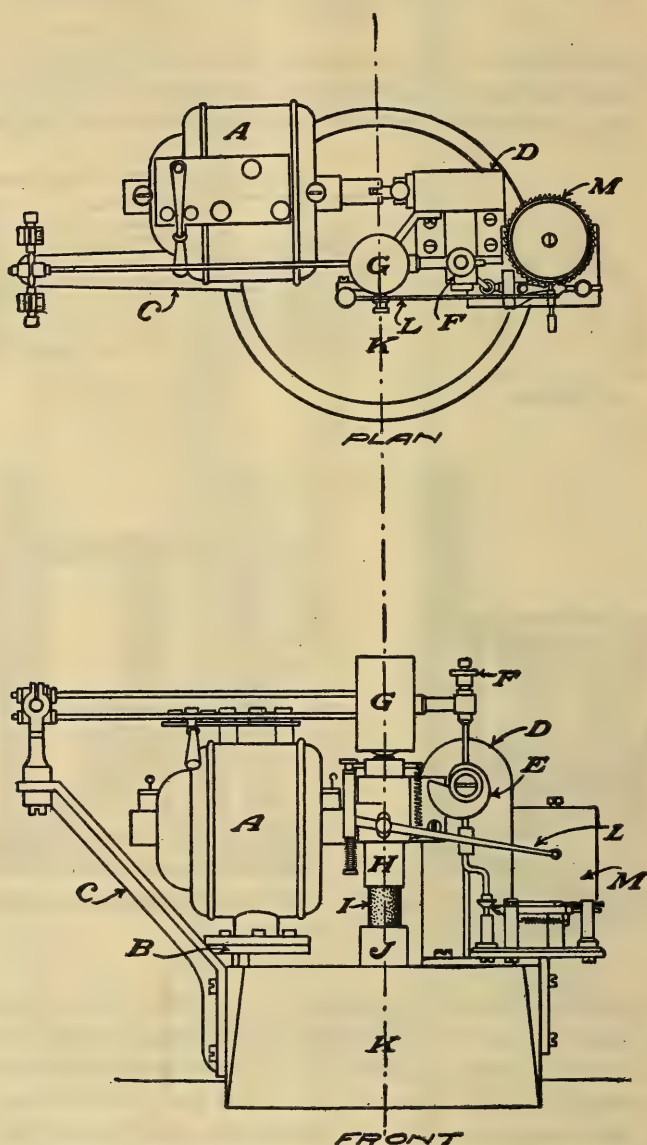


FIG. 11.—Details of Page impact machine for testing cementing value.

per square centimeter. At the moment the lever arm is raised the pressure should be released. The briquette is then removed as shown in figure 10 and its height carefully measured. Add or subtract 1

gram from the material forming the next briquette for each millimeter variation from 25 in the height of the trial specimen. Six briquettes 25 mm. high should be made from each sample. They are allowed to dry in the air at ordinary room temperature for 20 hours after making, and are then dried at a temperature of 100°C . for four hours, cooled for 20 minutes in a desiccator, and immediately tested. Briquettes should not be allowed to stand in the open air while waiting to be tested, but should be kept in the desiccator. In making the test the briquette is held in position on the anvil of the testing machine by means of a drop of thick shellac, extreme care being taken to see that there is perfect contact between the upper surface of the briquette and the plunger, as well as between its lower surface and the anvil. There will ordinarily be no difficulty in securing this result. In certain highly argillaceous materials, however, the shrinkage caused by drying out sometimes warps the briquette so that its two ends are not parallel. In such a case a perfect bearing can only be secured by very carefully grinding the end of the bri-

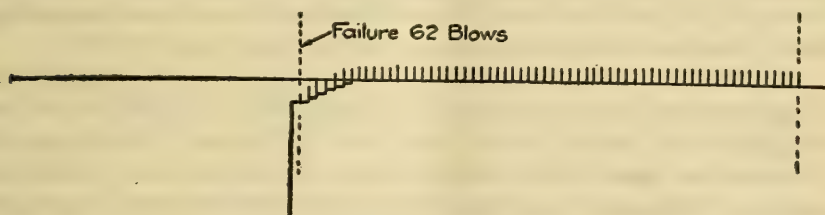


FIG. 12.—Record of cementing-value test.

quette on a piece of fine emery cloth until a satisfactory bearing is obtained. With the briquette in position, the plunger resting on it, and the cam in the position shown in figure 11, the end of the pin (F) is brought into contact with the surface of the cam and the locknut tightened. This will give an effective drop of 1 cm. to the hammer. The brass pencil is so adjusted that on revolving the drum a horizontal line will be traced on the sensitized paper which is wrapped tightly around it and held in place by a rubber band. On starting the motor, each blow of the hammer will then be recorded in a short vertical line above the base line. The number of blows required to destroy the resilience of the briquette will equal the number of vertical lines showing on the record above the base lines. A typical record is shown in figure 12. In counting the number of vertical lines showing on the record, no attention should be paid to the fact that the short horizontal lines gradually drop below the original base line. Each vertical line which shows above the corresponding horizontal base line on its right should be counted as part of the record. The typical record shown in figure 12 brings out this point clearly.

COMPUTATIONS.

The number of blows required to destroy the specimen is called its cementing value. An average of five determinations is taken.

VALUE OF THE TEST.

On account of the great number of variables entering into this test, some of which are very difficult to control, concordant results are not always obtainable. Also, certain types of rock, particularly some varieties of sandstone, give results that appear to be at variance with those obtained in actual practice. With this exception, however, the test will, if properly carried out, give a very good preliminary idea of the binding power of the material under examination. Results of this test vary enormously, running from 0 for pure quartz to as high as several thousand blows in the case of high-binding clays.

COMPRESSION TEST.

This test is not ordinarily made upon road-building rock. Since, however, it is included in certain specifications for rock used as paving block, it is made when requested in the following manner:

A cylindrical test specimen 2 inches in diameter and 2 inches high is prepared by the same method as previously described under the toughness test, except that a 2-inch core drill is used. Both ends of the specimen which have been properly faced are then bedded in plaster of Paris, and the cylinder crushed in a 200,000-pound universal testing machine. A small 2-inch spherical bearing block is placed between the moving head of the machine and upper surface of the specimen. The average of at least two determinations are reported as the crushing strength calculated in pounds per square inch.

APPENDIX A.

Samples of road-building rock are tested free of charge by the Office of Public Roads and Rural Engineering for any citizen of the United States provided the samples are submitted strictly in accordance with full printed instructions, which are sent on request. The following forms are used by this laboratory in connection with the work of rock testing:

Form 6—Rev.

UNITED STATES DEPARTMENT OF AGRICULTURE,
OFFICE OF PUBLIC ROADS AND RURAL ENGINEERING,
WASHINGTON, D. C.

INSTRUCTIONS FOR SELECTING AND SHIPPING SAMPLES.

In order to have road materials tested in the laboratory of the Office of Public Roads and Rural Engineering the instructions below must be carefully followed:

1. All samples shall be selected to represent as nearly as possible an average of the material.

2. A sample of rock for laboratory tests shall consist of stones which will pass through a 3-inch but not through a 1½-inch ring—*excepting one piece*, which should measure approximately 4 by 6 inches on one face and be about 3 inches thick. The whole sample shall weigh not less than 25 pounds. It is desired that samples of rock be shipped in strong burlap bags.

3. A sample of gravel shall weigh not less than 25 pounds. Such samples must be shipped in boxes or bags sufficiently tight to prevent the finer material from sifting out. In selecting samples of gravel great care should be exercised in order to obtain material that is an average of the run of pit.

4. Samples of sand, clay, or marl must weigh at least 10 pounds and should be shipped in strong cloth bags or tight boxes.

5. A sample of cement should weigh at least 10 pounds and be shipped in a strong, tight cloth bag.

6. A blank form and addressed tag envelope will be supplied by the Office for each sample. The blank form must be filled out and placed in the tag envelope, which must be securely fastened to the bag and used as the address for the sample. It is essential that the blank forms be filled out with the utmost care, as they are filed as records of the samples. A form, properly filled out, *must* be attached to *each* sample.

7. The Office desires to keep a record of the actual wear on roads built of the materials tested. If the material which this sample represents has been or is about to be used on roads, this Office desires to be informed of the addresses of those in charge of the construction and maintenance of such roads.

8. Samples may be shipped, freight, express, or parcel post, and must be *fully prepaid*.

9. The Office makes no charge for tests.

LOGAN WALLER PAGE, *Director*.

Form 5.

UNITED STATES DEPARTMENT OF AGRICULTURE,
OFFICE OF PUBLIC ROADS AND RURAL ENGINEERING,
WASHINGTON, D. C.

The sample of road material described below is a
(Stone, sand, gravel, etc.)

From the property of

Located at
(Town.) (County.) (State.)

Submitted by

At request of

Date of shipment Via Wt. lbs.

Approximate quantity of material available

Individual identification mark

It is desired that this material be tested to determine its suitability for use as follows:

NOTE.—In order to have the proper tests made, it is essential that the above statement be as complete as possible.

Has material been used on roads? If so, where, in what type, and with what results?

Do not write below this line.

LABORATORY RECORD.

Date received Serial No.

Condition of sample

Receipt acknowledged

Form 16.

UNITED STATES DEPARTMENT OF AGRICULTURE,
OFFICE OF PUBLIC ROADS AND RURAL ENGINEERING,
WASHINGTON, D. C.

....., 191 .

DEAR SIR:

Your sample of....., No.
from.....

has been received and will be tested in the order of its arrival.

Very truly yours,

.....
Director.

Remarks.....

U. S. OFFICE OF PUBLIC ROADS AND RURAL ENGINEERING.
DIVISION OF ROAD MATERIAL TESTS AND RESEARCH—ROCK TESTS.

Serial No. From (County.) (State.) Name

SPECIFIC GRAVITY—ABSORPTION.		ABRASION.		HARDNESS.	
(1)	(2)	No. pieces.		(1)	(2)
Wt. in air.....		Initial wt.....		Initial wt.....	
Wt. in water.....		Final wt.....		Final wt.....	
Loss in wt.....		Under $\frac{1}{8}$ in.....		Loss 1,000 rev.....	
Wt. 96 hrs.....		Per cent wear.....	Fr. coef.....	Loss..... rev.....	
Gain 96 hrs.....		Tested by.....	Compt....., Chk.....	Hard. coef.....	
Sp. gr.....		Avg. hard. coef.....			
Absorption.....		Tested by....., Compt....., Chk.....			
Sp. gr.....; Wt. cu. ft.....					
Abs. lbs. cu. ft.....					
Tested by....., Compt....., Chk.....					
CEMENTING VALUE.					
1..... 2..... 3..... 4..... 5.....					
Avg. No. blows.....					
Tested by....., Compt....., Chk.....					
Remarks.....					

Reported.....

Form 20.

UNITED STATES DEPARTMENT OF AGRICULTURE,
OFFICE OF PUBLIC ROADS AND RURAL ENGINEERING,
WASHINGTON, D. C.

Report on sample No. of road material from
Made at the request of
Material.....

DETERMINATIONS.

Specific gravity.....	.....
Weight per cubic foot.....	 pounds.
Water absorbed per cubic foot.....	 pounds.
Per cent of wear.....	.....
French coefficient of wear.....	.....
Hardness.....	.....
Toughness.....	.....
Cementing value.....	.....
Remarks.....	.....

Respectfully,

_____, Assistant Director.

APPENDIX B.

EQUIPMENT OF A ROAD-MATERIAL TESTING LABORATORY.

A complete list of all apparatus necessary to carry on the work of rock testing follows:

- 1 Deval abrasion machine having four cylinders.
- 1 impact machine for toughness test.
- 1 Dorry machine for hardness test.
- 1 impact machine for cementing-value test.
- 1 cementing-value briquette-forming machine.
- 2 ball mills.
- 1 diamond core drill, with suitable drill press.
- 1 diamond saw.
- 1 grinding lap.
- 5 pounds No. 120 carborundum.
- 1 small jaw crusher.
- 1 scale, capacity 5 kilograms and sensitive to 0.5 gram.
- 1 scale, capacity 100 grams and sensitive to 0.1 gram.
- 1 balance, capacity 100 grams and sensitive to 0.01 gram.
- 1 large drying oven.
- 1 small drying oven, with temperature-regulating device.
- 1 10-inch desiccator, with calcium chloride.
- 1 millimeter scale.
- 1 dozen pint jars with metal screw caps.
- 1 dozen 3-quart enameled iron pans.
- 1 100 c. c. graduate.
- 1 100 c. c. beaker.
- 1 15-inch standard sieve, with 30 meshes per linear inch.
- 1 15-inch standard sieve, with 40 meshes per linear inch.
- 1 16-inch sieve, reinforced with square openings one-sixteenth of an inch in size.

100 burlap bags about 17 inches square.
500 blank tags.
1 50-pound anvil,
1 10-pound sledge.
1 3-pound double-face stone hammer.
1 1½-pound single-face stone hammer.
1 6-inch scoop.
1 barrel quartz sand between No. 30 and No. 40 sieves.
1 50-pound bale of waste.
1 waste can.
1 oil can and motor oil.

This equipment should be sufficient to enable a force of three men to maintain an average of 24 routine rock analyses per week. The complete cost of equipping a laboratory as outlined above should not exceed \$1,500 and would probably not reach this figure if some of the larger machines were shaft driven instead of direct connected.

**PUBLICATIONS OF THE UNITED STATES DEPARTMENT OF AGRICULTURE
RELATING TO ROADS AND ROAD-BUILDING MATERIALS.**

AVAILABLE FOR FREE DISTRIBUTION.

Repair and Maintenance of Highways. (Roads Bulletin 48.)
Highway Bonds. (Department Bulletin 136.)
Road Models. (Department Bulletin 220.)
Portland Cement Concrete Pavements for Country Roads. (Department Bulletin 249.)
Sand-clay and Burnt-clay Roads. (Farmers' Bulletin 311.)
Macadam Roads. (Farmers' Bulletin 338.)
Benefits of Improved Roads. (Farmers' Bulletin 505.)
The Road Drag and How it is Used. (Farmers' Bulletin 597.)
Oil-mixed Portland Cement Concrete. (Department Bulletin 230.)

FOR SALE BY THE SUPERINTENDENT OF DOCUMENTS.

The Construction of Macadam Roads. (Roads Bulletin 29.) Price, 10 cents.
Road Materials of Southern and Eastern Maine. (Roads Bulletin 33.) Price, 20 cents.
Examination and Classification of Rocks for Road Building, Including the Physical Properties of Rocks with Reference to their Mineral Composition and Structure. (Roads Bulletin 37.) Price, 15 cents.
Methods for the Examination of Bituminous Road Materials. (Roads Bulletin 38.) Price, 10 cents.
Constructing Macadamized Roads. (Roads Circular 21.) Price, 5 cents.
Bitumens and their Essential Constituents for Road Construction and Maintenance. (Roads Circular 93.) Price, 5 cents.
Vitrified Brick Pavements for Country Roads. (Department Bulletin 246.) Price, 10 cents.
Use of the Split-log Drag on Earth Roads. (Farmers' Bulletin 321.) Price, 5 cents.
Selection of Materials for Macadam Roads. (Separate 204 from the Yearbook 1900.) Price, 5 cents.

UNITED STATES DEPARTMENT OF AGRICULTURE



BULLETIN No. 348



Contribution from the Office of Public Roads and Rural
Engineering, LOGAN WALLER PAGE, Director

Washington, D. C.

PROFESSIONAL PAPER

April 4, 1916

RELATION OF MINERAL COMPOSITION AND ROCK STRUCTURE TO THE PHYSICAL PROPERTIES OF ROAD MATERIALS.

By E. C. E. LORD, *Petrographer.*

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Examination and classification of rocks for road making.....	2	Effect of secondary minerals on the physical properties of rocks for road building.....	13
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INTRODUCTION.

The importance of selecting proper materials for the construction of macadam roads has become generally recognized and has led to a careful study in this office of a large number of rocks in order to properly determine their mineral composition and road-making properties. The earlier results of these investigations, which were published in 1911,¹ have demonstrated that certain physical properties are in a general way characteristic of definite rock types and may be attributed to the peculiar arrangement and composition of the rock-forming constituents. With a largely increased number of samples available for examination it has been found possible to correlate these relations more exactly, and in the present publication the results obtained will be presented with special reference to the effect of secondary minerals on the physical properties of rocks for road building.

In considering these results it should be noted that owing to the complexity of the subject and of the possible effect of many variables, it has not been possible to develop definite laws. The discussion of the effect of secondary minerals has therefore been based necessarily

¹ Examination and Classification of Rocks for Road Building, U. S. Office of Public Roads Bul. 37.

upon their tendency to influence the physical characteristics of the rocks in which they occur.

It will be found desirable to outline, in advance, the method employed by this office in the analysis and classification of road materials, as well as to review briefly the mineral composition of rocks and the manner in which their more important physical properties have been determined.

EXAMINATION AND CLASSIFICATION OF ROCKS FOR ROAD MAKING.

Upon receipt of the rock sample, which, according to printed instructions, should weigh not less than 30 pounds and be collected with care to represent as nearly as possible an average of the whole rock outcrop, it is examined in a general way to determine the proper method of analysis.

Both rocks consisting chiefly of the carbonate minerals (limestone and dolomite) as well as unconsolidated deposits (clay, gravel, sand) are subject to chemical or mechanical analysis when necessary, whereas all other materials are examined microscopically to determine the quantitative proportions of the minerals present in the rock sample. To carry out a quantitative analysis of this kind it is necessary to prepare a thin section of the sample so that its mineral

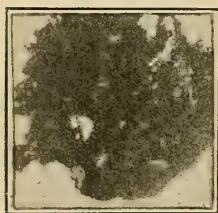


FIG. 1.—Thin section of rock mounted on glass.

constituents may be readily recognized and measured. Figure 1 represents such a section of rock mounted in Canada balsam.

The section is prepared by grinding down with emery powder on a revolving iron disk a representative chip from a hand sample of the rock until a smooth, flat surface is obtained. The chip is then firmly attached to a thick glass plate of appropriate size by means of Canada balsam, with the prepared flat surface against the glass, and the grinding continued on the opposite surface until the section approaches the thickness of tissue paper and becomes transparent, when it is transferred to an object glass and attached by means of the balsam, and finally covered with a very thin cover glass. The minerals present in the slide are then identified under the microscope and their relative proportions determined by means of a measuring apparatus devised by L. W. Page. This consists of an ordinary fixed eyepiece having a square field of about 1 centimeter area divided into 100 equal parts, as shown in figure 2.

With the aid of this crossline micrometer, each square of which is 1 one-hundredth or 1 per cent of the whole field, the relative proportions, expressed in percentage, of the minerals occupying the field can be readily determined by simply noting the number of squares covered by each mineral in turn. The average results of 20 such

rocks for road making.

Temperature.	Hypersthene.	Titanite.	Apatite.	Zeolite.
.....	0.2	0.1	0.1	.....
.....	0.2	0.2	0.2	.....
.....	.....	0.5	0.1	.....
.....	.....	0.5	0.3	.....
.....	(3)	0.2	0.3	0.8
0.2	2.3	.....	0.1	(3)
7.5	20.0	.....	.....	.....
.....	.....	0.2	(3)	.....
10.8	.....	.....	.....	(3)
10.6	.....	.....	.....	0.6
11.8	.....	.....	.....	1.0
10.8	.....	.....	.....	.....
10.7	.....	0.2	.....	0.7
1.	.....	.....	0.4	.....
1.	.....	.....	0.1	.....
1.	.....	.....	(3)	.....
1.	.....	.....	.....	.....
1.	.....	.....	.....	(3)
.....				
.....	.....	0.1	0.2	.....
.....	.....	0.2	0.3	.....
.....	.....	0.5	0.3	.....
.....	.....	0.3	0.1	.....
.....	.....	.....	0.1	.....
.....	.....	0.3	.....	.....
.....	.....	0.6	0.1	.....
.....	0.6	0.8	0.1	.....
.....				
.....	.....	.....	(3)	.....
.....	.....	0.2	0.3	.....
.....	(3)	.....	0.6	.....
.....	0.3	.....	0.3	.....
.....				
.....				

ntial minerals which are chara

TABLE 1.—Average mineral composition and physical properties of rocks for road making.

No.		Samples tested.	Rock varieties.	Mineral composition, expressed in percentages.																							Physical properties. ¹										Rock varieties.	Samples tested.	No.	
				Quartz.	Orthoclase.	Plagioclase.	Augite.	Hornblende.	Biotite.	Muscovite.	Calcite.	Dolomite.	Chlorite.	Kaolin.	Epidote.	Magnetite.	Limonite.	Microcline.	Rock glass.	Garnet.	Olivine.	Pyrite.	Serpentine.	Hypserthene.	Titanite.	Apatite.	Zoelite.	Zircon.	Nepheline.	Opal.	Tourmaline.	Rutile.	Silimanite.	Specific grav- ity.	Per cent of wear.	Hardness.				Toughness.
1	165	Granite.....	29.5	41.0	7.8	0.1	(²)	2.7	2.4	0.3		1.4	6.5	1.4	0.4	0.9	4.0		6.3		(²)		0.2	0.1	0.1		(²)					2.66	3.7	18.3	12	24	Granite.....	165	1	
2	51	Biotite-granite.....	27.1	36.0	9.0	(²)	0.1	10.0	1.2	0.1		0.6	6.9	1.9	0.7	0.2	5.4		(²)		(²)		0.2	0.2	0.2		(²)					2.68	3.6	17.9	9	23	Biotite-granite.....	51	2	
3	20	Hornblende-granite.....	22.7	33.6	11.8		0.4	12.6	8.8	0.2	0.3		1.3	10.1	0.3	1.4	0.2	1.1			(²)		0.5	0.1			(²)					2.70	2.8	18.6	13	20	Hornblende-granite.....	20	3	
4	23	Augite-syenite.....	3.7	45.0	6.9	7.9	1.4	4.0	0.4	0.7		2.0	10.6	2.8	3.2	1.0	7.0				0.1		0.5	0.3								2.87	3.0	18.2	17	30	Augite-syenite.....	23	4	
5	78	Diorite.....	8.0	7.1	30.0	2.7	27.0	3.5	0.1	0.6		2.2	8.2	5.4	2.3	0.2					0.6		(²)	0.2	0.3	0.8		1.1				2.87	3.0	17.7	11	47	Diorite.....	78	5	
6	50	Gabbro.....	0.5		44.2	25.4	8.8	2.0	0.2			2.9	6.4	1.2	2.1	0.2					0.2		0.2	0.1		(²)						2.97	3.0	17.7	11	47	Gabbro.....	50	6	
7	4	Peridotite.....			16.0		0.6								30.6	0.3					5.0		27.5	20.0								2.92	4.0	14.2	11	52	Peridotite.....	4	7	
8	43	Rhyolite.....	32.0	44.6	2.8		0.7	3.0	2.0	1.3		3.7	3.1	2.2	1.5	2.6	(²)	0.4			0.1			(²)	(²)		(²)					2.56	3.7	18.3	19	118	Rhyolite.....	43	8	
9	6	Trachyte.....	3.2	41.8	1.0	2.3	0.9	0.5		2.6		3.4	14.4	3.1	2.7	4.5		0.4						0.2	(²)		(²)					2.73	2.9	18.1	24	102	Trachyte.....	6	9	
10	67	Andesite.....	0.6		48.0	11.4	8.4			1.1		5.7	2.0	3.1	2.1	4.7		12.5				0.3			(²)			0.4				2.66	3.9	17.9	18	139	Andesite.....	67	10	
11	70	Basalt.....			35.6	33.3				(²)		0.9		4.5	1.4		(²)	20.6				3.0			0.6		0.6					2.86	2.8	17.8	20	38	Basalt.....	70	11	
12	106	Altered basalt.....	0.2		32.1	31.3				1.5		8.0					11.8				1.3		1.8		1.0							2.33	3.0	16.9	18	141	Altered basalt.....	106	12	
13	29	Dabase.....			44.2	46.0				(²)		1.5	0.9				1.9				1.3		0.8									3.00	2.2	18.3	23	30	Dabase.....	29	13	
14	231	Altered diabase.....	0.8		55.0		2.3	0.3		1.0		15.4	0.2	2.6	4.1	0.4		0.6			0.2		0.7		5.2		0.7					2.93	2.6	17.7	19	164	Altered diabase.....	231	14	
15	875	Limestone.....	6.0						88.8	7.9			1.6				0.6															2.65	5.0	14.1	9	54	Limestone.....	875	15	
16	331	Dolomite.....	5.3						11.1	81.5			1.2				0.6															2.72	5.5	14.9	9	33	Dolomite.....	331	16	
17	109	Sandstone.....	79.1	4.8	0.3		0.2	1.1	0.5			0.7	3.5	(²)	0.4		9.0		(²)		0.2				(²)		0.1					2.56	6.2	14.4	10	51	Sandstone.....	109	17	
18	191	Feldspathic sandstone.....	35.4	56.4	1.6		0.5	1.5	3.0			2.7	22.5	0.9	0.6		3.9				(²)					0.1						2.62	6.2	14.6	13	50	Feldspathic sandstone.....	191	18	
19	53	Calcareous sandstone.....	46.4	2.8	1.3		0.1	0.1	41.6			2.4	0.9	0.7	0.3	2.7					0.2				(²)		0.1					2.69	4.2	15.3	11	69	Calcareous sandstone.....	53	19	
20	62	Chert.....	93.1	0.1				0.2	1.0			0.1	0.6			0.1	1.2				0.7		(²)									2.94	9.4	18.2	12	30	Chert.....	62	20	
21	167	Granite-gneiss.....	37.3	32.1	2.9	0.1	(²)	6.7	10.9	0.2		1.1	2.1	2.2	0.6	0.3	2.7		0.2		0.1			0.1	0.2		0.1					2.71	4.5	17.7	10	24	Granite-gneiss.....	167	21	
22	62	Biotite-gneiss.....	31.4	33.2	5.9		0.6	19.1	1.8	0.1		1.2	1.4	1.8	0.3	0.2	1.8		1.0		0.1			0.2	0.3		0.1		(²)	0.3		2.75	5.8	16.6	9	37	Biotite-gneiss.....	62	22	
23	62	Hornblende-gneiss.....	9.6	16.1	14.8	3.3	44.8	2.6	0.6			0.7	0.8	1.9	2.1	0.1	0.1		0.9		0.0			0.1			0.1					3.7	17.6				Hornblende-gneiss.....	18	23	
24	42	Mica-schist.....	96.7	18.0	1.5			13.0	25.0	0.3		2.0	0.1	2.4	1.5	0.1			0.3		0.2			0.3	0.1		0.1					2.77	5.4	16.9	10	36	Mica-schist.....	42	24	
25	17	Biotite-schist.....	31.2	13.0	3.2	0.1	1.0	37.8				(²)	1.0	2.1	1.5	0.4			1.5		0.2			0.2		0.1		(²)				2.80	4.6	16.1	11	42	Biotite-schist.....	17	25	
26	68	Chlorite-schist.....	10.5	0.7	10.1		4.6	3.1		1.5		39.3	23.9	3.5	0.5				0.1		0.2			0.3								2.90	4.3	15.4	14	45	Chlorite-schist.....	68	26	
27	68	Hornblende-schist.....	10.1	3.2	11.7		6.5	60.6		0.2	0.3	1.4	0.5	6.8	3.0	0.2			0.9		0.3			0.8	0.1		0.8					2.95	4.4	17.0	16	30	Hornblende-schist.....	68	27	
28	22	Amphibolite.....	2.6	1.3	8.1		70.3	0.9	0.2			1.8		11.8	1.4	0.5			0.1		0.1			0.6	0.8	0.1						3.02	2.8	17.5	19	42	Amphibolite.....	22	28	
29	71	Slate.....	23.1	2.7	(²)			0.8	54.5	1.8		0.8	1.6	2.0	1.9	3.1			0.1		0.4			(²)	(²)		0.1					2.78	4.4	15.0	17	57	Slate.....	71	29	
30	61	Quartzite.....	88.7	8.3	0.2		1.1	2.3	1.8	1.4		0.7	1.2	2.0	0.4	1.4			(²)		0.5			0.2	(²)		0.1					2.65	3.3	18.9	17	11	Quartzite.....	61	30	
31	22	Feldspathic quartzite.....	46.4	37.1	1.6	(²)		2.2	4.8	0.7		3.0	0.9	1.4	1.1	1.3			(²)		0.2			0.2	(²)		0.1					2.99	2.9	18.3	20	26	Feldspathic quartzite.....	22	31	
32	11	Pyroxene quartzite.....	29.4	19.8	15.0	25.8	0.8	1.0				0.3	0.7						4.3		0.5			0.6			(²)	0.2				2.97	2.9	18.2	19	14	Pyroxene quartzite.....	11	32	
33	8	Epidote.....	5.5	5.5	15.4	10.9	2.3					0.6	0.4	1.3					25.5		0.2			0.3			(²)					3.10	2.4	18.1	19	13	Epidote.....	8	33	
34	13	Epidote.....	14.4	6.4	0.1		4.9	0.1	0.5	(²)				70.1													(²)					2.99	3.5	18.0	17	32	Epidote.....	13	34	
35	61	Marble.....	2.8	0.2	0.2			0.1		95.8	0.4		1.5				0.3																2.77	5.7	13.1	6	34	Marble.....	61	35

¹ For explanation of figures representing physical properties, see text, pages 17-20.² Figures in bold type indicate the essential minerals which are characteristic of the rock variety.[†] Trace.

NOTE.—The information given in this table is correct up to Jan. 1, 1914.

17715—Boll. 343-16. (To face page 2.)

measurements taken in various parts of the section will, under ordinary conditions, give the volumetric proportions of the minerals in the rock itself. If desired, the chemical composition of the rock may be approximately obtained by multiplying the volumetric percentages of all the minerals present by their specific gravities and reducing the whole to a basis of 100, and then multiplying the values obtained by the percentages of the chemical components, reckoned as oxides, belonging to each mineral.¹

The average mineral composition and physical properties of all rock samples analyzed and tested in this office up to January 1, 1914, are given in Table 1.

The material has been arranged in groups following the general classification adopted by this office, which is as follows:

TABLE 2.—*General classification of rocks.*

Class.	Type.	Family.
I. Igneous.....	1. Intrusive (plutonic)...	a. Granite.
		b. Syenite.
		c. Diorite.
		d. Gabbro.
	2. Extrusive (volcanic)...	e. Peridotite.
		a. Rhyolite.
		b. Trachyte.
		c. Andesite.
II. Sedimentary.....	1. Calcareous.....	d. Basalt and diabase.
		a. Limestone.
	2. Siliceous.....	b. Dolomite.
		a. Shale.
III. Metamorphic....	1. Foliated.....	b. Sandstone.
		c. Chert (flint).
		a. Gneiss.
	2. Nonfoliated.....	b. Schist.
		c. Amphibolite.
		a. Slate.
		b. Quartzite.
		c. Eclogite.
		d. Marble.

Referring to Table No. 1, Nos. 1 to 7 embrace plutonic igneous rocks; 8 to 14, volcanic igneous rocks; 15 to 20, sedimentary rocks; and 21 to 35, metamorphic rocks or crystalline schists. The average percentages of essential minerals characterizing each rock variety are printed in bold type and the minerals themselves placed in the table approximately in the order of their importance as rock-forming constituents.² The relative value of these various rock types from a road-making standpoint may be best understood after a brief discussion of their mode of origin and mineral characteristics. Under igneous rocks (Nos. 1 to 14) are included all varieties of road material that have solidified from a state of liquid fusion, the structure or manner of mineral aggregation being influenced largely by the rate of cooling of the fused rock magma. Thus, intrusive or plutonic

¹ Bulletin 37, Office of Public Roads, pp. 10-11.

² The mineral composition of limestone, dolomite, and marble has been obtained from chemical analyses of about 100 samples.

rocks (Nos. 1 to 7), such as granite, diorite, gabbro, etc. (Pls. I, fig. 1; II, figs. 1, 2), having cooled slowly at great depths below the earth's surface, usually possess large and well-developed mineral components, whereas extrusive or volcanic varieties (Nos. 8 to 14), cooling more rapidly upon the earth's surface, are finer grained and frequently show so-called porphyritic structures owing to the development of larger crystals in a dense, fine-grained ground mass. (Pls. I, fig. 2; III, figs. 1, 2.)

Sedimentary rocks (Nos. 15 to 20), on the other hand, are made up of mineral or shell fragments that have been transported mainly by water and deposited in sea or lake depressions in more or less parallel layers and subsequently cemented together through pressure

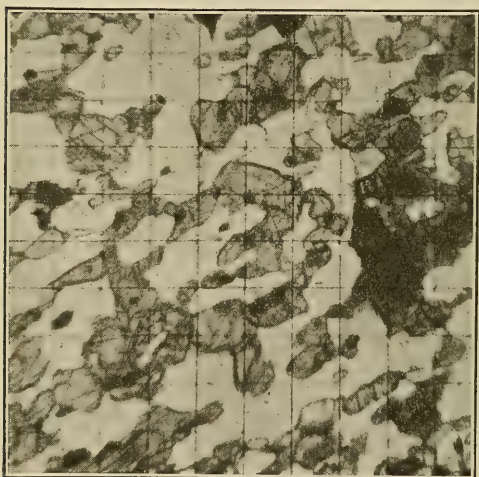


FIG. 2.—Cross-line field illustrating method of estimating minerals in thin section.

and the formation of secondary mineral compounds. (Pls. IV, fig. 1; V, fig. 2). Rocks of this class are usually distinctly bedded or stratified. Metamorphic rocks occupy in a measure an intermediate position between those of igneous and sedimentary origin, and are either foliated or schistose (Nos. 21 to 28) through the parallel arrangement of their mineral constituents (Pl. VI), or massive and nonfoliated (Nos. 29 to 35) like marble and quartzite (Pl. V, fig. 1).

These structures have been induced by long-continued shearing and compressive forces acting alike on igneous and sedimentary rocks, thereby changing to a greater or less degree the composition and structure of the original rock masses.

MINERAL COMPOSITION OF ROCKS FOR ROAD MAKING.

Although the road materials tested in this office have been separated into 35 distinct varieties, yet it will be seen that but 12 minerals enter prominently into their composition. Some idea of the general appearance of these minerals when perfectly developed may be obtained from the photographs reproduced on Plate VII, yet the fact should be borne in mind that when present as rock-forming aggregates these regular crystal shapes are considerably modified and the minerals appear in more or less irregular forms depending upon the character of the rock in which they occur. (Pls. I-III.)

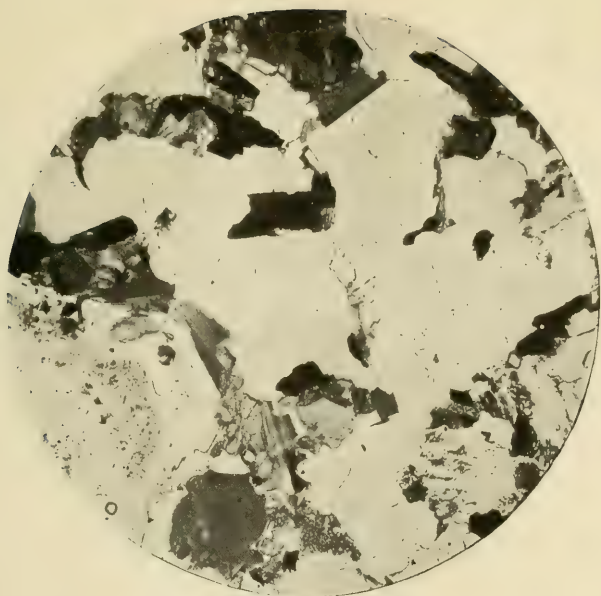


FIG. 1.—GRANITE.

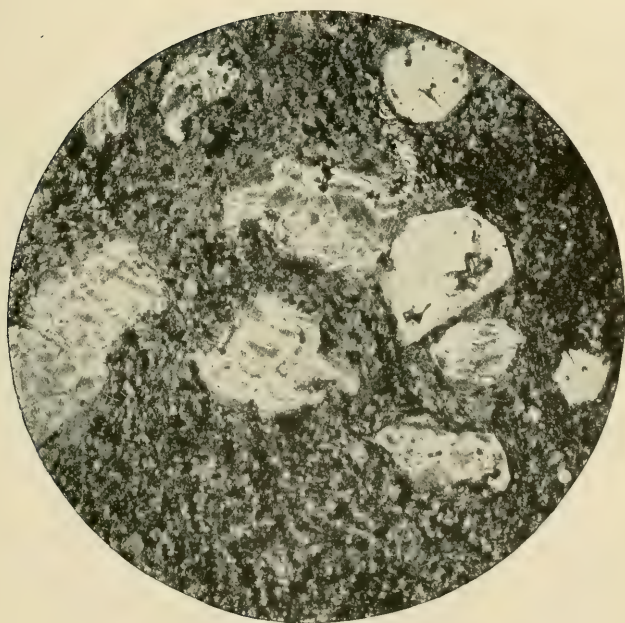


FIG. 2.—RHYOLITE.
IGNEOUS ROCKS.

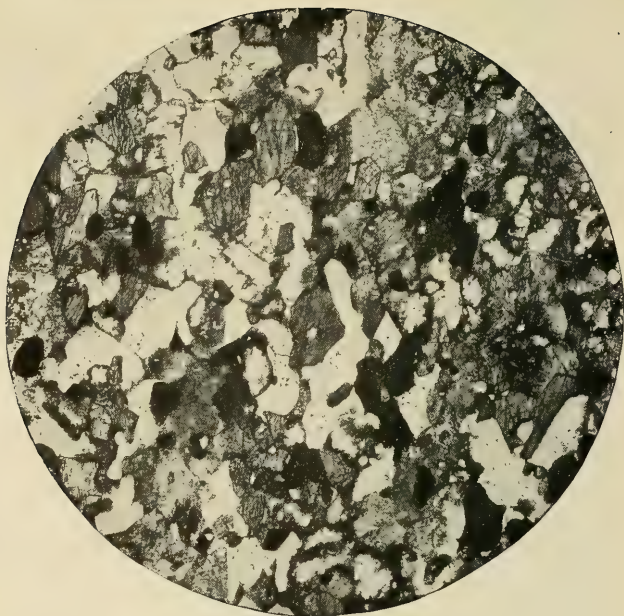


FIG. 1.—DIORITE.

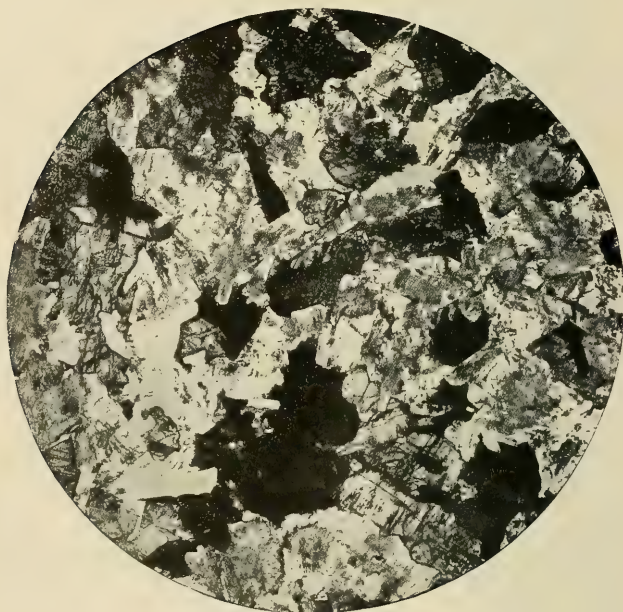


FIG. 2.—GABBRO.

IGNEOUS ROCKS.

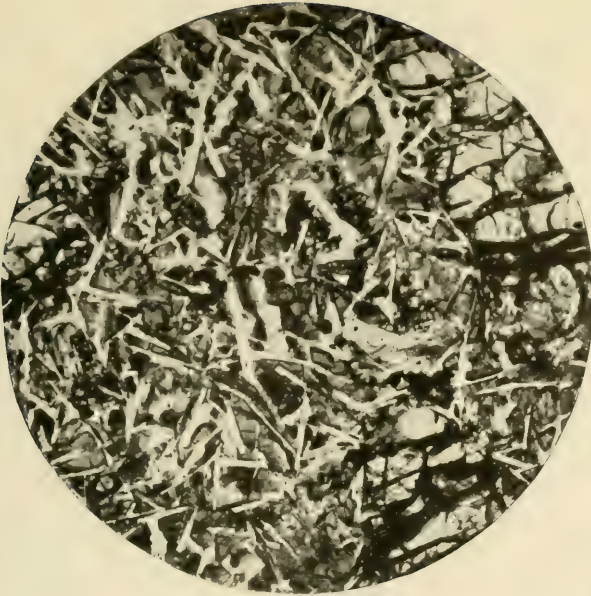


FIG. 1.—BASALT (TRAP).



FIG. 2.—DIABASE (TRAP).

IGNEOUS ROCKS.

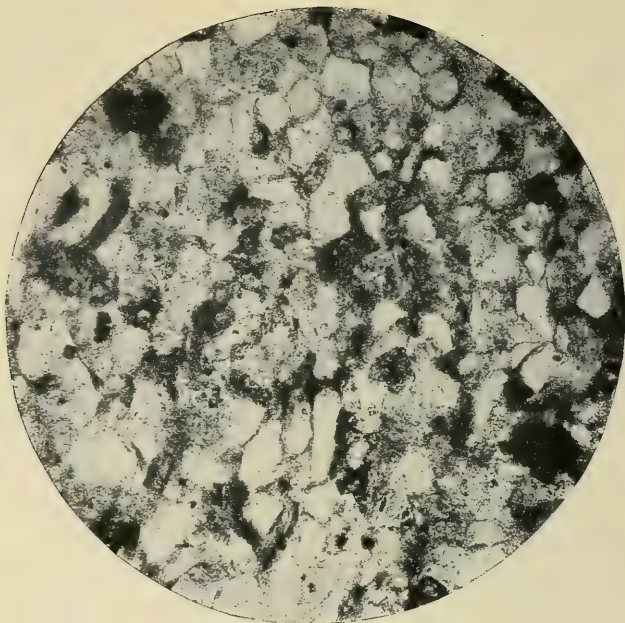


FIG. 1.—SANDSTONE.

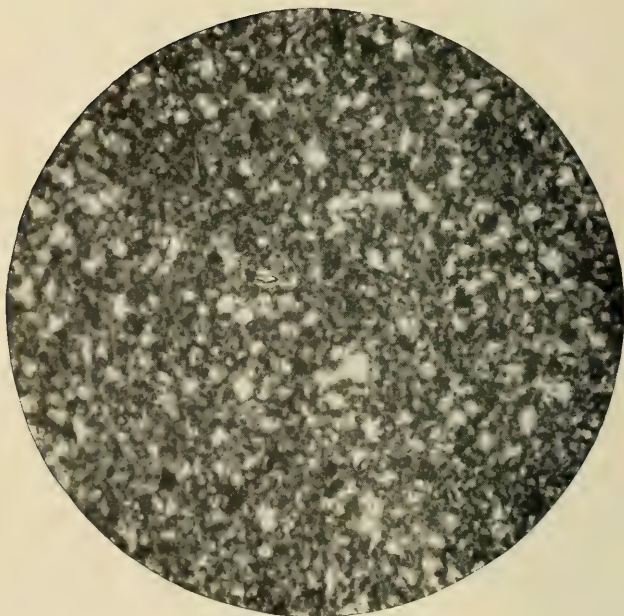


FIG. 2.—CHERT.

SEDIMENTARY ROCKS.



FIG. 1.—QUARTZITE.



FIG. 2.—FOSSILIFEROUS LIMESTONE.

SEDIMENTARY AND METAMORPHIC ROCKS.



FIG. 1.—GRANITE-GNEISS.

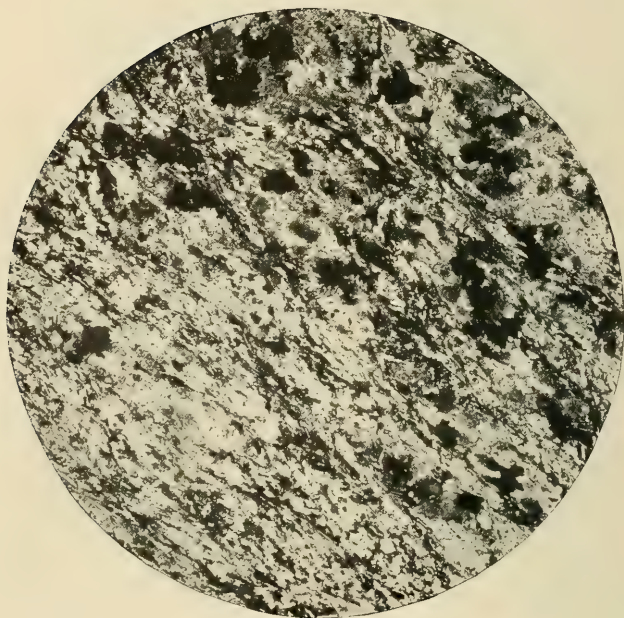


FIG. 2.—MICA-SCHIST.

METAMORPHIC ROCKS.

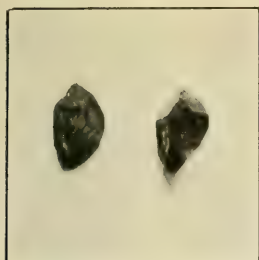


FIG. 1.—QUARTZ.

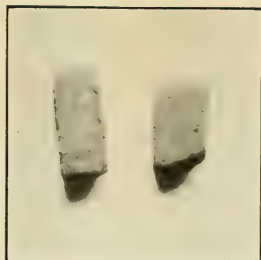


FIG. 2.—ORTHOCLASE.



FIG. 3.—PLAGIOCLASE.

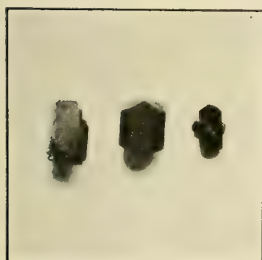


FIG. 4.—AUGITE.



FIG. 5.—HORNBLLENDE.

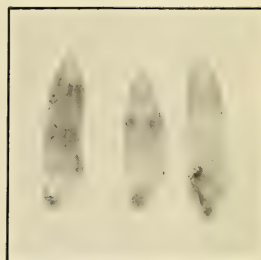


FIG. 6.—CALCITE.



FIG. 7.—CHLORITE.

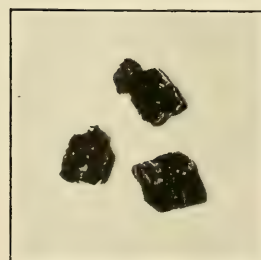


FIG. 8.—BIOTITE.

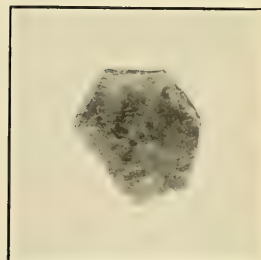


FIG. 9.—MUSCOVITE.

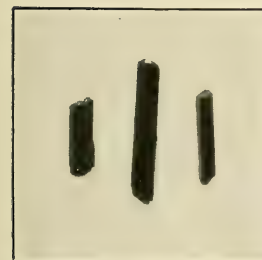


FIG. 10.—EPIDOTE.



FIG. 11.—MAGNETITE.

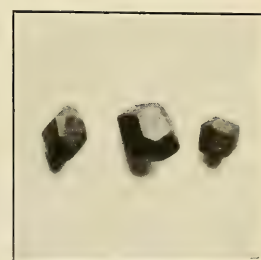


FIG. 12.—GARNET.

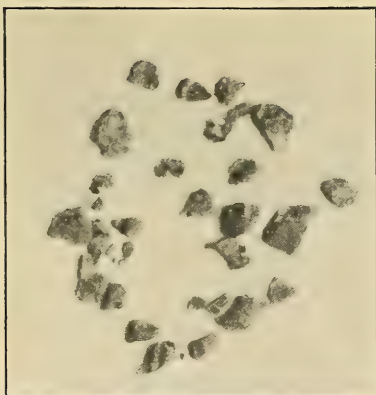


FIG. 1.—GRANITE.

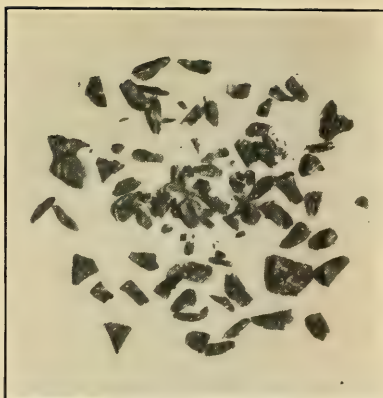


FIG. 2.—RHYOLITE.

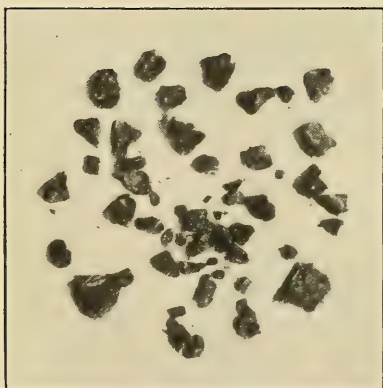


FIG. 3.—GABBRO.



FIG. 4.—DIABASE.

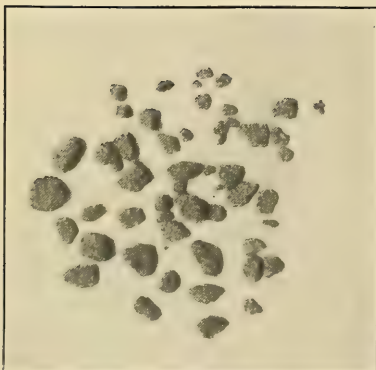


FIG. 5.—SANDSTONE.

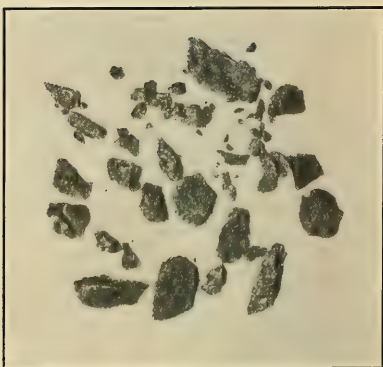


FIG. 6.—SCHIST.

SCREENINGS FROM ROAD-MAKING ROCKS.

Furthermore, the microscope reveals certain peculiarities which are not discernible with the naked eye. Thus, plagioclase feldspar crystals (Pl. VII, fig. 3), that appear perfectly homogeneous in the hand sample, are seen under the microscope to be made up usually of a great number of smaller individual crystals arranged in a characteristic manner, or again, certain constituents such as augite and hornblende (Pl. VII, figs. 4 and 5) are distinguished by microscopic lines of parting (cleavage) that intersect at definite angles quite distinct from each other. As these minerals all differ in chemical composition, their optical properties are also different; that is, when light passes through a transparent thin section of a rock under a microscope with properly adjusted Nicol prisms, certain minerals will appear in beautiful rainbow colors, while in others these interference colors may be of a lower order and much fainter. Again not infrequently some components are encountered that show no optical reaction whatever and remain consequently dark through an entire revolution of the microscopic stage. These characteristic optical properties greatly facilitate the identification of the various rock-forming constituents.

The chemical composition of a rock magma necessarily influences or controls the formation of minerals within the rock. Thus certain magmas, rich in silica and potash, embracing so-called acid rocks, produce on cooling light-colored granite and rhyolite (Pl. I, figs. 1 and 2), composed chiefly of quartz, orthoclase, and mica (Pl. VII, figs. 1, 2, 8, and 9); while other magmas having less silica and more iron and lime give rise to darker basic or trap rocks, such as diorite, gabbro, diabase, and basalt (Pls. II and III), made up chiefly of hornblende, plagioclase, augite, and magnetite (Pl. VII, figs. 3, 4, 5, and 11). The mineral components of sedimentary rocks are dependent in composition on the character of the materials from which their sediments were derived, as well as upon the nature of the matrix cementing them. Calcareous deposits, therefore (Table 1, Nos. 15-16), derived chiefly from shell fragments (Pl. V, fig. 2), consist essentially of calcite and dolomite (Pl. VII, fig. 6), with varying amounts of quartz, kaolin, and iron oxide as impurities, while sandstones (Table 1, Nos. 17-20), formed from siliceous rock materials that have withstood the abrasive effects of transportation, are made up mainly of quartz and kaolinized feldspar fragments cemented together by calcite, limonite, or silicified clay (Pl. IV, fig. 1). Chert, or flint (Pl. IV, fig. 2), differs somewhat from a normal sandstone in that it is composed chiefly of very finely divided quartz frequently associated with opaline silica that originated from minute siliceous shells of marine animals through a process of chemical solution and deposition. The minerals present in metamorphic rocks are similar to those of igneous and sedimentary origin with the subsequent develop-

ment, through metamorphic agencies, of muscovite, chlorite, epidote, hornblende, garnet, etc. (Pl. VII, figs. 5, 7, 9, 10, and 12). Thus it has been found that granite passes over into gneiss and micaceous schist (Pl. VI), and from the more basic gabbro, diorite, etc., are developed amphibolite, chlorite schist, eclogite, etc., while sandstone and limestone give place, respectively, to quartzite (Pl. V, fig. 1) and marble.

The chief interest attached to the study of these minerals is to determine in what manner they affect the road-making qualities of rocks, and it will be, therefore, of interest to discuss somewhat in detail their more important physical properties.

In Table 3 are given the essential mineral constituents of rocks for road making, with their general chemical composition and volumetric percentages as determined from all samples thus far analyzed.

TABLE 3.—*Mineral constituents of rocks for road making.*

Primary minerals.			Secondary minerals.		
Name.	Chemical composition.	Volumetric percentages.	Name.	Chemical composition.	Volumetric percentages.
Quartz.....	Silica.....	17.8	Calcite.....	Carbonate of lime.....	26.5
Plagioclase...	Silicate of alumina, lime, and soda.	9.6	Dolomite....	Carbonate of lime and magnesia.	10.4
Orthoclase...	Silicate of alumina and potash.	8.8	Kaolin.....	Hydrous silicate of alumina.	4.2
Augite.....	Silicate of lime, magnesia, iron, and alumina.	6.0	Chlorite.....	Hydrous silicate of magnesia, iron, and alumina.	2.7
Hornblende...	do.....	3.1	Epidote.....	Hydrous silicate of lime, iron, and alumina.	1.7
Muscovite....	Hydrous silicate of alumina and potash.	2.4	Limonite....	Hydrated oxide of iron....	1.2
Biotite.....	Hydrous silicate of alumina, iron, magnesia, and potash.	1.7	Serpentine..	Hydrous silicate of iron and magnesia.	0.1
Rock glass...	Variable.....	1.5	Talc.....	Hydrous silicate of magnesia.	0.1
Magnetite...	Magnetic oxide of iron....	1.2	Zeolite.....	Hydrous silicate of alumina, lime, and soda.	0.1
Garnet.....	Silicate of alumina, iron, and lime.	0.2	Opal.....	Hydrated silica.....	0.1

It will be noted that these constituents have been divided into two groups—primary minerals, or such that constitute the original components of igneous rocks and form the essential part of metamorphic schists, and secondary minerals that have been derived from the former through subsequent processes of alteration.

In the case of certain volcanic rock magmas (basalt, rhyolite, andesite), where the rate of cooling has been very rapid, a glass base (rock glass) is frequently left after crystallization has ceased. This glass is extremely brittle and when present in appreciable quantities has a tendency to lower the indicated wearing properties of the rock.

PRIMARY MINERALS.

Quartz (Pl. VII, fig. 1) is without doubt the most widely distributed mineral in the earth's crust and is found in greater or less abundance in all kinds of road materials excepting the more basic types of unaltered igneous rocks (traps) and certain varieties of basic crystalline schists (amphibolites, eclogites). It has a specific gravity of 2.66 and is extremely hard, standing No. 7 in the Mohs scale of hardness.¹ It is characterized in the rock sample by irregular, rounded shape, without parting planes (cleavage), and breaks readily into splintery glass-like fragments. Quartz sometimes appears as a secondary mineral in finely crystalline aggregates (chalcedony), often associated with opal or hydrated silica. It will be shown later on that where quartz is present in large quantities, especially when firmly consolidated, as in the case of fine-grained igneous and massive metamorphic rocks, the resulting material is extremely hard and offers great resistance to wear.

Orthoclase (microcline) and *Plagioclase* feldspars (Pl. VII, figs. 2 and 3) are among the principal ingredients of igneous and metamorphic rocks and certain types of sandstones. They vary in specific gravity from 2.54 to 2.76, according to composition, and in hardness from 6 to 6.5. (Mohs scale.) These minerals occur as rock constituents frequently in well-defined, tabular-formed or lath-shaped crystals characterized by perfect cleavage along planes at, or approaching, right angles to each other. Because of this cleavage, many coarse-grained feldspathic rocks break down readily under impact into fragments having very characteristic cubical shapes. When present, however, in fine-grained aggregates closely intergrown with quartz, augite, or other minerals, the effect of cleavage is not apparent and the resulting rocks are extremely hard and tough.

Augite and *Hornblende* (Pl. VII, figs. 4 and 5) form the chief iron-bearing or dark silicate constituents of basic igneous rocks (traps) and the crystalline schists derived from them. They have a hardness of 5 to 6.5,² specific gravity of 2.93 to 3.71, and occur usually in more or less elongated, prismatic shapes, with well-defined cleavage parallel to the prism planes. Owing to their peculiar form, these crystals interlock very compactly with adjoining minerals, especially lath-shaped, plagioclase feldspar, thereby developing the most durable types of road material (traps).

Biotite (black mica) and *Muscovite* (white mica) are at home chiefly in granitic rocks and in micaceous schists and gneisses. Their specific gravity varies from 2.7 to 3.2, with hardness of from 2 to 3.²

¹ This scale as described in Merrill's *Rocks, Rock-weathering and Soils*, p. 12, is based upon the relative hardness of the following minerals arranged in ascending order: (1) Talc, (2) gypsum, (3) calcite, (4) fluorite, (5) apatite, (6) orthoclase, (7) quartz, (8) topaz, (9) corundum, and (10) diamond.

² Mohs scale.

Common mica is readily recognized in the hand sample by a thin plate-like crystal form, frequently with hexagonal outline (Pl. VII, figs. 8 and 9) and more especially by a perfect basal cleavage which causes the crystals to part readily into thin elastic flakes. The foliation characterizing many types of metamorphic rocks is caused largely by the parallel arrangement of mica laminae, which is also largely responsible for the poor wearing properties of this material.

Magnetite and *Garnet* (Pl. VII, figs. 11 and 12) are found as essential constituents in but two types of road material (peridotite and eclogite). They occur in well-defined crystal form without cleavage and are extremely heavy (specific gravity 5.18–3.15), and hard (5.5–7.5¹) and in some cases materially increase the wearing properties of the rock. (See Table 7, No. 13.)

Besides the above-mentioned primary minerals others are found widely distributed in various kinds of road materials, but generally in such small quantities as not to affect appreciably the physical character of the rocks. Among these accessory constituents may be mentioned hypersthene, olivine, titanite, apatite, zircon, and pyrite.

SECONDARY MINERALS.

Under secondary minerals will be considered only the more important products of rock decay brought about mainly by the chemical action of water and carbonic acid on primary rock constituents.

Calcite and *Dolomite* (Pl. VII, fig. 6) are the chief constituents of limestones and dolomites and so far as they have formed upon the first consolidation of this material might consistently be classed as primary. In all other rock types these carbonates are distinctly of secondary origin and formed by the chemical combination of carbonic acid with lime and magnesia derived either directly from the disintegration of primary constituents or introduced later from extraneous sources. These minerals have approximately the same physical properties and can not be separated microscopically, but may be readily distinguished by their different behavior toward cold dilute acids; calcite being readily dissolved with vigorous ebullition of carbonic acid gas, while dolomite is very slowly acted on with barely perceptible effervescence. Calcite and dolomite are soft minerals (hardness 3–3.5¹), of moderate specific gravity (2.6–2.9), and occur always in a crystalline condition. The crystals are characterized by perfect cleavage in three directions corresponding with the planes of a rhombohedron and for this reason calcareous rocks as a rule break down readily into fine crystalline powders.

Kaolin is a very common product of rock decay, especially in temperate climates, and is derived to a large extent from orthoclase

¹ Mohs scale.

feldspar (Pl. VII, fig. 2) through a process of hydration and dissolution by which all of the potash and two-thirds of the silica present in the feldspar may be removed. Under somewhat different conditions of weathering secondary white mica (sericite) will result in place of kaolin, whereby the same amount of silica but only one-third of the potash originally present in the orthoclase are lost.¹ As the final product of feldspathic rock decay, kaolin is found, usually in large quantities, in clays and similar residual deposits.² Kaolin occurs either in well-defined, small crystal plates (kaolinite) resembling muscovite (Pl. VII, fig. 9), in physical properties (hardness 2-2.5,³ specific gravity 2.6-2.63), or in the form of minute, amorphous grains of very indefinite composition, often associated with iron oxide and opaline silica. In this condition kaolin acts as a colloid and influences very greatly the plasticity and cementing value of rock powders by increasing in volume, and becoming glue-like when wet and binding the mineral particles firmly together when dry.

Chlorite and *Epidote* (Pl. VII, figs. 7 and 10) are frequently associated as alteration products of augite, hornblende, dark mica (biotite), and plagioclase, and are consequently most abundant in trap rocks or in darker varieties of crystalline schists (Table 1, Nos. 12, 14, and 26). The process of alteration is similar to that already stated regarding kaolin and the products themselves are in many cases not unlike this mineral in physical properties. Chlorite is a soft green mineral found either in the form of well-developed, thin plates and folia resembling mica, or as very fine scales and fibers of indefinite composition (viridite) frequently accompanied by amorphous silica, calcite, and iron oxide. In the latter development, chlorite bears a close resemblance to kaolin in its effects on the cementing properties of road materials.

Epidote in contrast to chlorite, occurs as granular or prismatic crystal aggregates, derived chiefly from plagioclase feldspar when accompanied by iron-bearing compounds. It is a hard (6-7³), tough mineral with high specific gravity (3.25-3.5), yellowish green color and, when present in appreciable quantities, apparently increases the wearing qualities of rocks.

Other secondary minerals.—Among other products of rock decay may be mentioned limonite, serpentine, talc, opal, and zeolitic compounds. These minerals are, with the exception of the harder crystalline zeolites (chabazite and natrolite), very indefinite in crystal form or entirely amorphous (opal and limonite), and are not readily separated by means of the microscope.

¹ H. Rosenbusch, *Elemente der Gesteinslehre*, 3d edition, p. 79.

² H. Niklas: *Die Kolloidchemie und ihre Bedeutung für Bodenkunde, Geologie und Mineralogie*. Inter. Mittl. für Bodenkunde, Vol. III, 1913, p. 395.

³ Mohs scale.

PHYSICAL PROPERTIES OF ROAD MATERIALS.

From what has been said it is apparent that many kinds of minerals associated in different ways enter into the composition of rocks for road building. It will now be of interest to discuss briefly the physical properties of the rocks themselves before taking up more specifically the relationship between these properties and the mineral composition and structure of road materials.

The physical properties selected for this investigation are expressed upon determination by laboratory tests, as follows: (1) Per cent of wear or loss by abrasion, (2) hardness, (3) toughness, (4) cementing value, and (5) specific gravity.

Per cent of wear represents the amount of material under 0.16 cm. in diameter lost by abrasion from a quantity of rock fragments as nearly uniform in size as possible and weighing within 10 grams of 5 kilograms. This carefully weighed sample which should contain about 50 pieces of rock is tested in a Deval type of abrasion machine consisting of a cast-iron cylinder, 34 cm. deep by 20 cm. in diameter, closed at one end and having a tight-fitting cover at the other. The cylinder is attached to a horizontal shaft so that the axis is inclined at an angle of 30° with that of the shaft and revolved for 5 hours at the rate of 2,000 revolutions per hour, during which the rock fragments are thrown from one end of the cylinder to the other twice in each revolution. This abraded material is then thoroughly dried and screened through a $\frac{1}{16}$ -inch mesh sieve and from the amount lost the per cent of wear is determined. This loss may be also expressed by the French coefficient given below:

$$\text{Coefficient of wear} = 20 \times \frac{20}{W} = \frac{400}{W} = \frac{40}{\text{per cent of wear}}$$

where W is the weight in grams of the abraded material under 0.16 cm. ($\frac{1}{16}$ inch) in diameter per kilogram of rock used.¹

Hardness is the resistance which a material offers to the displacement of its particles by friction and the test is made on a cylindrical rock core, 25 millimeters in diameter. The test piece is held perpendicularly under a constant pressure of 1,250 grams, against a revolving cast-steel disk, while standard quartz sand, between 30 and 40 mesh, is used as the abrasion agent. From the average loss in weight computed from two runs, the coefficient of hardness is obtained by deducting one-third of this loss, expressed in grams per 1,000 revolutions, from an arbitrary constant (20).

Toughness, as here understood, is the resistance a material offers to fracture by impact. The test piece is a cylindrical rock core 25 millimeters high by 25 millimeters in diameter, and the test is made

¹ Bulletin 347, U. S. Dept. Agriculture, p. 6.

with an impact machine constructed on the principle of a pile driver. The blow is delivered by a hammer weighing 2 kilograms, raised by a sprocket chain and released automatically by a concentric electro-magnet to fall on an armor-piercing steel plunger with spherical lower end which is in contact with the upper surface of the test piece. The test consists of a 1 centimeter fall of the hammer for the first blow and an increased fall of 1 centimeter for each successive blow until failure of the test piece occurs. The number of blows required to cause rupture represents the toughness.

The cementing value is the property possessed by a rock dust to cement or bind together the coarser rock fragments, and the test is carried out as follows: One-half kilogram of rock is broken sufficiently small to pass a half-inch-mesh screen and is then moistened with 90 cubic centimeters of water and placed in a cast-iron ball mill, containing two cast-steel shot, 5 inches in diameter and weighing about 20 pounds each. The sample is ground for $2\frac{1}{2}$ hours at the rate of 2,000 revolutions per hour or until the material has been reduced to a thick dough, the particles of which are not above 0.25 millimeter in diameter. The dough is then removed and molded into cylindrical briquettes 25 millimeters in diameter and 25 millimeters high, in a hydraulic briquette-forming machine, so adjusted as to give a maximum momentary pressure of 132 kilos per square centimeter on the compressed material. Five briquettes are made from each test sample which, after being thoroughly dried at 200° F. and cooled in a desiccator, are broken by an especially designed impact machine having a 1-kilogram pendulum hammer with an effective drop of 1 centimeter. The average number of blows required to destroy the bond of cementation in five briquettes determines the cementing value of the rock sample.

Specific gravity is the weight of the material compared with that of an equal volume of water, and is obtained by dividing the weight in air of a rock fragment by the difference between its weight in air and water. The weight per cubic foot of rock is found by multiplying the specific gravity by 62.37 pounds, the weight of a cubic foot of water.

GENERAL RELATION BETWEEN THE PHYSICAL PROPERTIES OF ROCKS AND THEIR MINERAL COMPOSITION AND STRUCTURE.

The general relation of rocks as expressed by average mineral composition and physical properties may be seen from the results of the tests and analyses given in Table 1. In the first place it will be noticed that igneous rocks as a class (Nos. 1-14), owing to their more uniform structure and preponderance of hard silicate components, have better indicated wearing properties than either sedimentary rocks or crystalline schists. As previously stated, these igneous rocks

have been separated into plutonic (Nos. 1-7) and volcanic varieties (8-14). The former, embracing rocks of granitic character, are in general less tough and have indicated wearing properties inferior to their finer-grained, volcanic equivalents. This may be ascribed directly to their coarser grain and to the marked effect of feldspathic cleavage (see p. 7). It will be observed, furthermore, that among the plutonic rocks those varieties unusually rich in mica (No. 2) and secondary serpentine (No. 7) have exceptionally low indicated wearing properties, whereas samples containing hornblende and augite in appreciable quantities are relatively tougher and in general offer greater resistance to abrasion (Nos. 3-6). In regard to the cementing value of plutonic rocks it will be seen that the quartzose varieties (Nos. 1, 2, 3, and 5) are lower than types in which quartz is absent, or present only in subordinate quantities (Nos. 4, 6, and 7).

The high toughness and excellent indicated wearing properties of volcanic rocks is in accordance with their fine grain and close interlocking mineral structure. The results of the tests indicate that siliceous varieties (No. 8) are on the whole harder though less tough than the more basic rocks to which trap belongs (Nos. 9-14). It will be observed, also, that samples rich in glass (Nos. 10, 11, and 12) are lower in hardness and toughness than their corresponding wholly crystalline varieties (Nos. 13 and 14). The latter are, furthermore, characterized in general by a peculiar intergrowth of plagioclase and augite (ophitic structure) which indicates greatly increased durability. (Pl. III). The average cementing values of fresh trap varieties (Nos. 11 and 13) are much below the corresponding varieties that have undergone alteration (Nos. 12 and 14), although superior to the latter in other respects.

Considering briefly the group of sedimentary rocks (Nos. 15-20) it will be noted that they are characterized in general by a lower toughness and hardness and higher per cent of wear, owing to the presence of soft, readily cleavable calcite and dolomite, as well as to a more open texture resulting in the case of the sandstones from incomplete cementation. (See p. 4.)

Metamorphic rocks have been divided into foliated (Nos. 21-28) and nonfoliated or massive varieties (Nos. 29-35). The former, owing to the peculiar parallel arrangement of their mineral constituents or schistose structure (Pl. VI) are comparatively low in toughness and indicated wearing properties except when hornblende is present in appreciable quantities (Nos. 27 and 28). Nonfoliated varieties, on the other hand, representing the direct result of compact crystallization without shearing of quartz, and hard silicates such as hornblende, augite, epidote, and garnet, are exceptionally hard and tough but usually deficient in cementing properties (Nos. 30-34).

The before-mentioned differences in physical properties of rocks for road making find expression also in the shapes of their smaller fragments as shown in Plate VIII.

It will be observed that the screenings from coarse-grained plutonic rocks after removal of the fine dust (figs. 1 and 3) are more rectangular in shape than those from finer-grained volcanics of similar composition which appear splintery and wedge-shaped (figs. 2 and 4). These characteristic shapes may be ascribed, as previously indicated, to the cubical cleavage of coarse, granular feldspar in the plutonic rocks and to the denser structures developed in the finer-grained rock types. The peculiar rounded shape of more loosely textured sandstones and the flat, lath-like appearance of fragments from schistose rocks (figs. 5 and 6) are noteworthy and may be associated directly with the mode of origin and mineral composition of this material. (See pp. 4-6.)

Regarding the binding effect of these rock types on the road it can be stated in general that the tough wedge-shaped fragments from fine-grained igneous rocks are inclined to produce a firmer and more permanent bond with the coarser road stones when properly compacted than is obtained with the more cubical or rounded screenings from granite and sandstone or with the lath-shaped schists and gneisses. This interlocking of the coarser rock fragments under the roller may be termed the mechanical bond of the road surface as distinguished from the cementing bond or binding effect produced by the finer rock dust when sufficiently moistened and compressed. In discussing the mineral composition of road materials this cementing property has been attributed largely to the peculiar quality of certain amorphous compounds closely related to kaolin and chlorite in composition. It will now be of interest to compare varying proportions of these compounds as well as other secondary minerals found in the more common rock types and note their effect on the cementing value and other physical properties of the rocks.

THE EFFECT OF SECONDARY MINERALS ON THE PHYSICAL PROPERTIES OF ROCKS FOR ROAD BUILDING.

The majority of rocks used for road building have been obtained from near the earth's surface or within the zone of atmospheric weathering,¹ and the extent of alteration varies greatly, depending upon composition, rock structure, and character and time of operation of the agencies involved. The resulting minerals are also manifold, being either softer products of hydration and oxidation, such as kaolin, chlorite, limonite, calcite, and opaline silica, or the harder silicates, epidote and zeolite, accompanied in some cases by secondary hornblende (actinolite) and quartz resulting from deeper-

¹ G. P. Merrill, *Rocks, Rock-Weathering and Soils*, 1906, p. 152.

seated processes of alteration. The effect of these secondary compounds is best demonstrated by arranging the various members of each rock class, so far as possible, into groups having approximately the same average proportions of alteration products.

IGNEOUS ROCKS.

In view of the great structural differences shown in rocks of this class it will be found of advantage to discuss separately the coarse-grained plutonic and fine-grained volcanic varieties. In Table 4 the average mineral composition and physical properties of plutonic rocks are given, arranged so far as possible in family groups having approximately like percentages of secondary constituents. These groups indicate an average of all samples having less than 5 per cent, from 5 to 10 per cent, and more than 10 per cent secondary minerals.

It will be observed in general that for a given family the toughness and hardness of these rocks tend to increase and the per cent of wear tends to decrease with additional amounts of secondary minerals, excepting in the case of very soft, highly kaolinized gabbro and serpentinized peridotite (Nos. 11 and 12). This improvement is less noticeable in granitic rocks (Nos. 1, 2, and 3) than in more basic varieties (Nos. 4-10) and may be attributed to the partial replacement of plagioclase feldspar by hard granular epidote (Nos. 3 and 5), accompanied in some cases by zeolites (No. 8) or actinolitic hornblende (No. 10).¹ The influence of secondary constituents is more apparent in regard to cementing value than to other properties. Thus it will be noted that altered varieties have a higher binding value than fresher samples and that the increase is roughly proportional to that of the secondary minerals. This increase, moreover, varies greatly in different rock types, reaching a maximum of 9 in the case of granites (Nos. 1-3), 31 in diorites (Nos. 6-8), 87 in gabbros (Nos. 9-11), and 92 in syenites (Nos. 4 and 5). It will be observed, furthermore, that the cementing value of siliceous varieties are in inverse relation to their quartz content. That is to say, granites, diorites, and syenites with averages of 28, 8, and 4 per cent quartz, respectively, have corresponding cementing values of 20, 34, and 90, indicating that the binding properties of coarse-grained rocks may be largely influenced by the physical character of the primary mineral components.

The effect of secondary minerals on the physical properties is more clearly demonstrated in the following group of volcanic rocks. This group embraces all fine-grained varieties of igneous rocks that, as shown in Table 5, are especially adapted to road building. The rocks have been arranged in families containing approximately like proportions of secondary minerals, obtained in the case of rhyolite and

¹ Office of Public Roads Bul. 37, p. 18.

TABLE 4.—*Mineral composition and physical properties of plutonic igneous rocks arranged according to average percentages of secondary minerals.*

Num- ber.	Samples analyzed.	Rock families.	Percentage of secondary minerals.						Percentage of essential primary minerals.										Physical properties.				
			Serpentine chlorite.	Kaolin.	Epidosite.	Calcite.	Limonte.	Zeolite.	Total.	Quartz.	Orthoclase.	Plagioclase.	Augite.	Hornblende.	Muscovite.	Biotite.	Magnetite.	Microcline.	Specific grav- ity.	Per cent of wear.	Hardness.	Toughness.	Cementing value.
1	99	Granite.....	{ 0.2	1.3	0.3	0.1	0.3	.....	2.1	29.6	43.2	9.3	.....	.....	2.7	5.8	.....	4.6	2.67	3.7	18.1	12	18
2	50		{ 0.5	5.3	0.8	0.1	0.4	.....	7.1	27.0	40.9	8.6	.....	.....	2.1	6.3	.....	3.6	2.65	4.0	18.4	11	20
3	53		{ 2.6	19.8	4.4	0.3	1.1	.....	28.2	26.0	26.1	9.9	.....	.....	1.0	6.0	.....	3.2	2.70	3.8	18.4	12	27
4	8	Syenite.....	{ 0.1	1.6	.....	0.1	.....	.....	1.8	4.9	53.0	8.7	8.3	.....	.....	3.4	.....	12.0	2.60	3.6	18.2	13	40
5	10		{ 5.3	18.4	5.1	1.2	1.8	.....	31.8	2.8	38.7	5.5	7.6	.....	.....	4.4	.....	2.6	2.77	3.9	18.2	14	132
6	22		{ 0.1	1.5	0.2	0.1	0.1	.....	2.0	8.4	8.7	32.5	.....	36.7	.....	4.5	.....	.....	2.92	3.3	17.9	15	20
7	24	Diorite.....	{ 1.1	5.1	3.8	0.9	0.1	.....	11.0	6.8	8.5	32.5	30.7	.....	.....	4.9	.....	.....	2.90	3.1	18.1	15	26
8	30		{ 6.4	15.6	10.4	0.7	0.3	3.1	36.5	8.3	4.5	25.7	17.1	.....	.....	1.6	.....	.....	2.85	2.9	18.2	20	51
9	18	Gabbro.....	{ 1.2	0.3	.....	.....	.....	.....	1.5	.....	.....	52.8	33.0	2.6	.....	.....	.....	.....	2.99	2.6	18.0	15	19
10	9		{ 3.7	2.1	0.9	.....	0.4	.....	7.1	.....	.....	39.4	33.9	14.5	.....	.....	.....	.....	2.99	2.4	18.6	20	37
11	10		{ 5.2	21.2	3.5	0.6	0.3	0.1	30.9	.....	.....	33.1	15.9	14.6	.....	.....	.....	.....	2.93	3.7	17.3	10	106
12	4	Peridotite.....	27.5	.....	.....	.....	0.3	.....	27.8	.....	.....	.....	36.0	.....	.....	.....	30.6	.....	2.93	4.0	14.2	11	76

TABLE 5.—*Mineral composition and physical properties of volcanic igneous rocks arranged according to average percentages of secondary minerals.*

No.	Samples analyzed.	Rock families.	Percentage of secondary minerals.						Percentage of essential primary minerals.							Physical properties.							
			Serpentine chlorite.	Kaolin.	Epidote.	Calcite.	Limonite.	Zeolite.	Opal.	Total.	Quartz.	Orthoclase.	Plagioclase.	Augite.	Hornblende.	Biotite.	Olivine.	Rock glass.	Specific gravity.	Per cent of wear.	Hardness.	Toughness.	Cementing value.
1	11	Rhyolite.	{	6.4	5.4	3.8	0.3	0.6	---	---	33.0	55.8	---	---	---	3.2	---	---	2.57	3.3	18.5	25	9
2	15																						
3	5	Trachyte.	3.4	14.4	8.1	2.6	4.5	---	---	33.0	3.2	41.8	---	---	5.8	---	---	9.4	2.68	2.9	18.2	23	115
4	4	Andesite.	{	7.2	2.2	3.4	2.4	5.5	0.1	0.8	---	---	47.0	20.4	8.7	---	---	21.0	2.65	4.8	17.1	11	23
5	24																						
6	27	Basalt.	{	0.05	---	---	---	0.05	---	0.1	---	---	34.4	36.1	---	---	1.8	24.7	2.83	2.8	17.9	22	11
7	44																						
8	31																						
9	23																						
10	15																						
11	13																						
12	6	Diabase.	{	0.1	1.1	---	---	0.1	---	0.1	---	---	41.3	51.3	---	---	2.1	1.3	3.00	2.5	18.0	31	13
13	24																						
14	24																						
15	14																						
16	21																						
17	43																						
			25.4	16.1	5.5	1.6	0.7	0.6	---	50.5	26.1	---	38.1	22.2	---	---	1.5	0.3	2.90	2.8	17.7	19	142
			15.7	7.1	---	1.0	0.2	1.4	---	26.4	---	---	42.4	31.6	---	---	0.3	1.6	2.97	2.4	17.9	20	118
			7.6	3.4	1.0	0.2	0.3	0.7	---	7.3	44.5	41.6	---	---	---	2.2	---	---	3.00	2.5	18.2	21	71
			4.7	1.8	0.5	---	0.1	0.2	---	8.7	44.9	44.7	---	---	---	---	1.0	2.0	3.00	2.2	18.3	24	34

andesite by averaging the analyses of fresh and altered varieties; and in the case of basalt and diabase, by averaging samples containing less than 1 per cent, from 1 to 5 per cent, from 5 to 10 per cent, from 10 to 20 per cent, from 20 to 30 per cent, and all above 30 per cent, of secondary minerals.

It will be observed in the first place that, in contrast to coarser-grained plutonic rocks the toughness and hardness of unaltered volcanics (Nos. 1, 6, and 12) are as a rule superior to those that have suffered from the effects of weathering. Exceptions will be noted, however, in the case of unaltered vitreous andesites (No. 4), which are low in toughness and indicated wearing properties on account of excessive glass content, and in that of certain highly altered varieties of trachyte, andesite, basalt, and diabase (Nos. 3, 5, 10, 11, and 17), which owe their relative high toughness and good indicated wearing properties to the development of hard secondary epidotes and zeolitic compounds combined with but little glass. The cementing values of volcanic rocks increase up to a certain point quite uniformly with increased proportions of alteration products, reaching a maximum in quartz-free rocks (Nos. 5, 11, and 17). Expressed numerically, this increase is 126 for rhyolite and 241 for andesite with equal percentages of secondary minerals (21.6 per cent), while basalt and diabase having about 50 per cent alteration compounds show a maximum increase of 201 and 129, respectively.

Comparing these results with the foregoing, it is apparent that the cementing property of volcanic rocks is on the whole superior to that of plutonic rocks having equal amounts of secondary minerals, and, furthermore, that this property is here less influenced by primary mineral composition—quartzose rhyolites binding almost as well as basalts (Nos. 1, 2, 6, and 10)—but is effected chiefly by differences in secondary compounds. This will be made clear by noting the average cementing values for basalt and diabase, which increase quite uniformly with the rate of decomposition where softer colloidal compounds, such as kaolin and chlorite prevail (Nos. 6–9 and 12–16). Beyond this point the presence of harder, more highly crystalline products of alteration (epidote, zeolite), indicating a less colloidal condition of the other secondary minerals, lowers the rate of increase (Nos. 11 and 17) or causes a falling off in binding properties (No. 10).

SEDIMENTARY ROCKS.

In discussing the origin of rocks it has been stated that road materials belonging to this class (limestones and sandstones) are formed chiefly by the cementing together of shell and mineral fragments or by chemical precipitation of amorphous silica (chert). While the mineral constituents of sandstones and cherts have been determined

TABLE 6.—*Mineral composition and physical properties of sedimentary rocks arranged according to average percentages of secondary minerals.*

Num- ber.	Samples analyzed.	Rock families.	Percentage of secondary minerals.						Percentage of essential primary minerals.						Physical properties.				
			Serpentine and chlorite.	Kaolin.	Epidote.	Calcite.	Limouite.	Total.	Calcite.	Dolomite.	Quartz.	Orthoclase.	Muscovite.	Biotite.	Specific grav- ity.	Per cent of wear.	Hardness.	Toughness.	Cementing value.
1	23	Limestone.	0.1	9.0	.....	.....	0.4	1.0	92.4	4.3	2.0	.....	.....	.....	2.64	5.1	12.0	8	49
2	40		.....	2.5	.....	.....	1.2	1.7	76.0	9.7	10.1	.....	.....	.....	2.66	4.0	14.3	11	80
3	8	Dolomite.	.....	1.4	.....	.....	0.4	1.8	7.1	90.0	0.6	.....	.....	.....	2.66	6.9	13.0	9	35
4	10		.....	1.1	.....	.....	0.8	1.9	15.9	71.7	10.0	.....	.....	.....	2.70	3.9	15.6	12	47
5	19	Sandstone.	0.2	0.8	.....	0.3	1.3	7.6	.....	.....	80.8	9.7	3.5	0.9	2.53	3.5	17.8	11	22
6	12		0.7	2.0	0.5	1.0	3.7	7.9	.....	.....	72.0	16.0	2.2	0.2	2.57	4.2	17.8	15	33
7	22	Sandstone.	0.9	6.7	.....	1.0	6.1	14.7	.....	.....	73.3	8.3	1.4	0.3	2.60	3.9	17.9	17	73
8	28		1.4	17.2	0.9	2.4	4.3	26.2	.....	.....	50.0	17.6	1.4	1.2	2.62	3.6	16.9	13	90
9	39	Chert.	2.8	23.3	0.6	4.0	5.0	35.7	.....	.....	36.5	24.0	1.7	0.2	2.65	3.6	16.3	16	78
10	30		3.7	16.7	1.0	16.4	10.9	48.7	.....	.....	29.3	18.8	0.6	0.2	2.70	3.7	16.6	12	62
11	11	.....	0.1	0.6	.....	.....	1.2	2.9	.....	.....	95.9	0.1	0.2	.....	2.54	9.4	18.2	12	30

microscopically, it was found necessary to subject limestones and dolomites to chemical analysis by means of which quartz, kaolin, and limonite could be separated quantitatively from the carbonate minerals. The results of the physical tests and mineral analysis of sedimentary rocks are given in Table 6. It will be seen that limestones and dolomites have been separated into groups having about equal quantities of quartz and secondary constituents, while sandstones have been divided into families representing averages of samples containing from 1 to 5 per cent, from 5 to 10 per cent, from 10 to 20 per cent, from 20 to 30 per cent, from 30 to 40 per cent, and above 40 per cent, of secondary minerals.

Comparing these results it will be observed in the first place that the average toughness and indicated wearing properties of calcareous rocks (Nos. 1-4) are as a rule inferior to sandstones (Nos. 5-10) while their cementing values are about the same. The exceptionally high percentage of wear found for chert (No. 11) may be explained by the fractured condition of this material caused by contraction on consolidation of the colloidal silica.¹

It will be noticed, furthermore, that varieties of limestone and dolomite containing an appreciable amount of quartz with some kaolin or clay (Nos. 2 and 4) are tougher and have lower percentages of wear and higher cementing values than samples deficient in these minerals (Nos. 1 and 3). It would appear also that limestones, owing to their greater solubility in water, cement better than dolomites.

Turning to the sandstones it will be observed that their toughness and cementing values increase proportionately with secondary components up to rocks averaging about 15 per cent (No. 7) and that beyond this point a general falling off in hardness and toughness takes place while the cementing value remains practically constant or decreases slightly with proportionately increased amounts of calcite (Nos. 9 and 10). It should be stated, however, that not only the quantity and quality of cementing material present in this class of road material but also the fineness of grain and density of structure influences the physical properties to a very marked degree.² Therefore it may be said that compact, fine-grained sandstones, having a moderate amount of siliceous clay cement (No. 7), produce harder and tougher material than rocks with deficient binder (Nos. 5 and 6) or such containing a large excess of calcareous clay cement (No. 10).

METAMORPHIC ROCKS.

The chief result of mineral alteration by metamorphic agencies is the development of highly crystalline rocks having characteristic structures, and composed of minerals very resistant to atmospheric weathering. For this reason the various types of foliated (Nos. 1-8)

¹ Office of Public Roads, Bul. 37, p. 27.

² J. Hirschwald. *Handbuch der bautechnischen Gesteinspruefung*, 1912, pp. 360-484.

TABLE 7.—Average mineral composition and physical properties of metamorphic rocks.

No.	Samples analyzed.	Rock varieties.	Percentage of secondary minerals.					Percentage of essential primary minerals.										Physical properties.						
			Serpentine and chlorite.	Kaolin.	Epidot.	Calcite.	Limonite.	Total.	Quartz.	Orthoclase.	Plagioclase.	Augite.	Hornblende.	Muscovite.	Biotite.	Garnet.	Epidot.	Chlorite.	Calcite.	Specific gravity.	Per cent of wear.	Hardness.	Toughness.	Cementing value.
1	67	Granite gneiss.....	1.1	2.1	2.2	0.2	0.3	5.9	37.3	32.1	2.9			10.9	6.7					2.65	4.7	17.9	10	25
2	45	Biotite gneiss.....	1.2	1.4	1.8	0.1	0.2	4.7	31.4	33.2	5.0			1.8	19.1					2.74	6.0	16.7	8	40
3	23	Hornblende gneiss.....	0.7	0.8	1.9	0.1	0.1	3.6	9.6	16.1	14.8	3.3	44.8	0.9	2.6					2.97	4.6	16.6	11	26
4	25	Mica schist.....	2.0	0.1	2.4	0.3	0.1	4.9	36.7	13.8	1.3			25.5	13.0					2.75	4.3	16.2	10	31
5	21	Biotite schist.....	1.0	2.1	2.1	0.7	0.4	4.2	34.2	13.0	3.2			3.0	37.8					2.77	4.6	16.2	11	40
6	11	Chlorite schist.....				1.5	0.8	2.3	10.5		10.1		4.6				28.3	39.5		2.98	4.6	16.5	15	31
7	61	Hornblende schist.....	0.4	0.5	6.8	0.3	0.2	8.2	10.1	3.2	11.7		60.6							3.01	3.6	17.0	17	36
8	20	Amphibolite.....	1.0		11.8	0.2	0.5	13.5	2.6	1.3			70.3							3.07	2.6	17.7	18	49
9	9	Slate.....	0.8	1.6	2.0	1.8	3.1	9.3	29.1	3.7				54.5						2.76	4.0	14.9	17	56
10	30	Quartzite.....	0.1	0.2	0.3	0.2	1.0	1.8	85.0	6.2			1.3	3.0						2.66	3.0	18.6	17	17
11	33	Altered quartzite.....	2.4	7.2	3.5	1.7	2.3	17.1	61.6	14.3				3.5	1.7					2.69	3.0	18.1	17	24
12	11	Pyroxene quartzite.....	0.3	0.7			0.5	1.5	29.4	19.3	15.0	23.8			1.0	3.4				2.98	2.9	18.0	21	17
13	8	Ecolite.....	0.4	1.3		0.6		2.3	5.9	5.5	25.4	15.4	10.9		2.3	28.5				3.10	2.4	18.4	22	19
14	13	Epidoite.....	1.5				0.8	2.3	14.4	5.4			4.9				70.1			2.59	3.5	18.0	17	32
15	5	Marble.....					0.3	0.3	2.8											2.77	5.7	13.1	6	34

and nonfoliated (Nos. 9–15) metamorphic rocks, given in Table 7 contain relatively low percentages of secondary minerals, and have not been further subdivided, with reference to these, except in the case of quartzites.

In comparing these rocks it will be noted that the foliated types, with the exception of more compact hornblendic varieties (Nos. 7 and 8), are lower in hardness, toughness, and indicated wearing properties than nonfoliated types excepting the highly micaceous slates (No. 9) and crystalline marbles (No. 15). It will be observed, furthermore, that the cementing value of metamorphic rocks is relatively low in

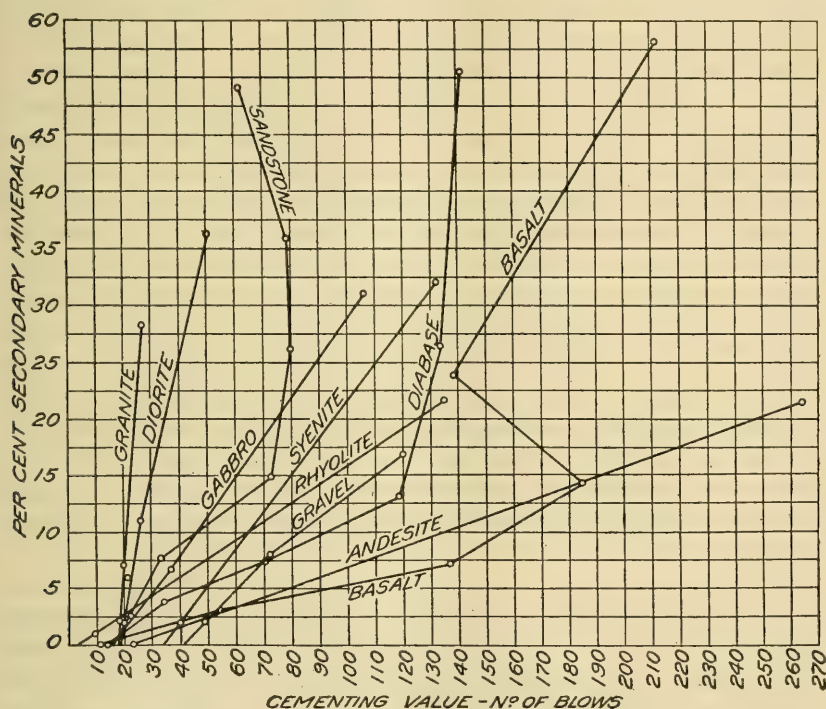


FIG. 3.—Effects of alteration products on cementing properties of rock powders.

accordance with low percentages of kaolin and secondary chlorite, reaching a maximum of 49 in amphibolite and 56 in slate (Nos. 8 and 9), with 13.5 per cent and 9.3 per cent, respectively, of secondary minerals, and a minimum of 17 in quartzites having each about 1.5 per cent decomposition products (Nos. 10 and 12). The very slight effect of even appreciable quantities of secondary minerals (No. 11) on the cementing properties of these highly quartzose rocks is similar to that found in acid granite (see p. 16), and may be attributed in both cases to the physical character of the quartz fragments combined with insufficient colloidal material. It will be of interest in this connection to compare these altered quartzites (No. 11), having

an average cementing value of 24, with decomposed sandstones showing an average binding value of 73 (Table 6, No. 7), and to note that the secondary products of the latter rocks consist almost entirely of colloids in the form of ferruginous clay (kaolin and limonite), while in the former crystalline epidote and chlorite are present in proportionately greater amounts.

The effects of alteration products on cementing properties of rock powders are shown in figure 3, where varying percentages of secondary minerals in rocks and gravels have been plotted against their respective cementing values. The great difference in binding properties between quartzose plutonic rocks (granite and diorite) and quartz-free types of the same class (syenite and gabbro), as well as between plutonic and volcanic rocks of similar composition, is clearly demonstrated. It will be observed also that where more complete curves could be drawn, as in the case of basalt, diabase, and sandstone, a critical point is reached at about 14 per cent of secondary minerals up to which the rate of increase in cementing value is almost directly proportional to that of these minerals, but beyond this point a marked deflection or break in the curves occurs in accordance with decreased cementing values resulting from largely increased proportions of highly crystalline products of alteration (epidote, zeolites, and calcite). The curve representing gravels from which the secondary minerals or clay content have been obtained by sifting through a 200-mesh screen and washing, indicates a relatively high cementing value up to samples containing 2 per cent clay, and shows that beyond this the relative increase corresponds in general to that of sandstone, reaching a maximum of 120 in samples having an average of 16.8 per cent of clay.

The property to slake in water is also common to many rock types, and as shown in Table 8 is largely dependent upon the physical character of the rock-forming constituents. The tests have been made by placing thoroughly desiccated briquettes of rock powders in water and noting the time required for their complete disintegration. Briquettes remaining intact for 24 hours in water are considered nonslaking.

It will be observed that the samples tested have been separated into acid and basic crystalline rocks (Nos. 1-4) and siliceous sedimentary rocks (Nos. 5 and 6), and the average mineral composition, time of slake, and cementing value given in each case. In comparing the results it will be noted that the nonslaking acid rocks (No. 1), while somewhat richer in secondary minerals, especially chlorite and epidote, contain a large excess of primary hornblende and considerably less quartz and mica than the slaking varieties (No. 2), while their cementing values are about the same. Nonslaking basic and

TABLE 8.—Average mineral composition, slaking properties, and cementing value of road materials.

No.	Samples analyzed.	Character of material.	Percentage of secondary minerals.						Percentage of primary minerals.											Time of slake in minutes.	Cementing value.	
			Kaolin.	Chlorite.	Epidote.	Calcite.	Limonite.	Zeolite.	Total.	Quartz.	Orthoclase.	Plagioclase.	Augite.	Hornblende.	Muscovite.	Biotite.	Magnetite.	Olivine.	Glass.			Garnet.	Total.
1	27	Acid crystalline rocks, nonslaking.....	9.2	4.2	2.6	0.8	1.3	.....	18.1	22.6	24.1	11.3	1.4	16.0	1.3	3.3	1.2	.....	.....	.....	81.9	21
2	42	Acid crystalline rocks, slaking.....	7.6	1.5	1.6	0.1	0.8	.....	11.6	34.8	25.6	9.4	.....	3.6	2.9	10.4	0.7	.....	.....	0.7	88.1	20
3	83	Basic crystalline rocks, nonslaking.....	2.0	7.2	0.4	0.5	0.2	0.9	11.2	0.8	0.6	35.1	31.7	1.9	.....	0.5	5.2	2.4	10.6	.....	88.8	63
4	48	Basic crystalline rocks, slaking.....	7.7	14.4	5.3	1.2	1.9	0.4	30.9	3.8	3.1	34.4	14.8	4.7	0.1	0.8	3.9	0.1	3.4	.....	69.1	124
5	9	Siliceous sedimentary rocks, nonslaking.....	1.3	1.1	.....	8.2	2.8	.....	13.4	74.2	8.5	0.6	2.7	0.3	.....	.....	.....	.....	.....	0.1	86.4	18
6	15	Siliceous sedimentary rocks, slaking.....	13.3	2.3	0.9	5.2	3.1	.....	24.8	53.2	15.7	3.3	.....	.....	1.1	1.4	0.5	.....	.....	.....	75.2	25

sedimentary rocks (Nos. 3 and 5), on the other hand, are distinguished from those that break down readily under water (Nos. 4 and 6) by a much lower percentage of colloidal secondary products (kaolin and chlorite) and by a corresponding decrease in cementing properties. From what has been said it is evident that basic crystalline and sedimentary rock powders with high cementing values and abundant secondary compounds have a marked tendency to slake, especially where the latter products are essentially colloidal in character, whereas the slaking property of acid crystalline rocks is influenced mainly by the relative abundance of primary quartz and mica and bears no very definite relation to secondary mineral composition and cementing properties.

SUMMARY AND CONCLUSION.

In the preceding pages a microscopic method of rock analysis by means of a crossline grating has been reviewed and the average mineral composition and physical properties of all rocks analyzed and tested in this office up to January 1, 1914, have been presented in tabular form. This material has been classified according to composition and structure and the rock-forming constituents have been discussed under the groups of primary and secondary minerals with a view to explaining their essential physical characteristics. The physical properties of rocks for road making and the method of testing this material have also been given and the results obtained used to show, first, in a general way, the relation between these properties and the mineral composition and structure of rocks; and secondly, to point out more specifically the effects of secondary compounds upon them. It has been found that igneous and nonfoliated metamorphic rocks owing to a preponderance of firmly united silicate minerals combined with uniformity in structure, offer a greater resistance to abrasion than other rock types, coarse-grained varieties being less tough and having inferior indicated wearing properties to those of finer grain in which the mineral components are more closely intergrown. Excessive quantities of glass in volcanic lavas and high percentages of readily cleavable mica and feldspar in plutonic rocks lower their toughness and indicated resistance to wear; on the other hand, appreciable quantities of hornblende and augite have an opposite effect. Foliated schists and gneisses parting readily along planes of schistosity are low in toughness while sandstones and limestones owe their inferior indicated resistance to wear either to incomplete consolidation or to a preponderance of softer carbonate minerals and clay.

It has been demonstrated, furthermore, that the shape and physical character of the smaller rock fragments used in road making are largely dependent upon structure and mineral composition, coarse-grained feldspathic rocks breaking down readily into rectangular fragments owing to feldspar cleavage, whereas the finer-grained trap screenings are more wedge-shaped and tougher. The chips broken from loosely compacted sandstones and schists are rounded in shape, approaching somewhat the outline of abraded quartz grains, or they appear flat and lath-shaped in accordance with the foliated structure of the latter rocks. The effect of weathering on the physical properties of rocks is clearly shown and varies with the structural character and composition of the rock and the physical properties and relative abundance of alteration products. Thus the indicated wearing properties of igneous and metamorphic rocks are, in general, benefited by hard secondary epidote, zeolite, and hornblende, while an abundance of softer alteration products such as chlorite, serpentine, and kaolin lowers the indicated resistance to wear.

In sedimentary limestones and dolomites it has been found that quartz accompanied by a little kaolin has greatly increased their toughness and resistance to abrasion, whereas compact sandstones having about 15 per cent of secondary constituents are among the most resistant of sedimentary rocks. The effects of weathering have been found most pronounced in regard to the cementing property of road materials, which is seen to vary directly, but not in the same ratio, with the amount of soft secondary minerals, in part amorphous. Where these materials are replaced, even to a limited extent, by harder, more crystalline products of alteration the binding properties are proportionately lowered. These relations have been plotted in curves for the common crystalline rock types and gravels.

Finally, the slaking properties of rock powders have been investigated with the result that acid crystalline rocks are found to slake rapidly excepting samples that contain relatively low average percentages of mica and quartz and abundant hornblende and epidote, while the slaking qualities of basic igneous rocks and sandstones are dependent mainly on the relative abundance of colloidal products of rock weathering, such as kaolin, limonite, and chlorite.

The results obtained from the present investigations indicate the following:

(1) Igneous and nonfoliated metamorphic rocks, owing to a preponderance of hard silicate minerals combined with greater uniformity in structure, are more durable than other road-making materials, finer-grained varieties offering greater resistance to abrasion than coarse-grained types.

(2) The resistance to wear of igneous and metamorphic rocks, containing an abundance of quartz, hornblende, augite, epidote, and garnet, is greater than that of similar rocks rich in mica, chlorite, serpentine, and calcite.

(3) Foliated metamorphic rocks, owing to the parallel arrangement of their mineral constituents, are, as a rule, deficient in toughness, and therefore not well adapted to road construction.

(4) Sedimentary rocks are usually deficient in wearing properties, except in the case of highly indurated sandstones, containing a moderate amount of siliceous clay, cement, and limestones or dolomites rich in quartz and having very little clay.

(5) Rocks for road making break down under impact into fragments, the shape and physical character of which are conditioned by mineral composition and structure.

(6) The effect of weathering is generally to lower the resistance to wear of road materials, owing to the development of soft, in part colloidal, products of alteration. Where the secondary minerals are harder and more crystalline the wearing properties of the rocks are proportionately increased.

(7) The cementing value of road materials is conditioned chiefly by the colloidal products of rock decay and increases in a general way proportionately with these products, reaching a maximum in rocks free from quartz.

(8) The slaking property of rock powders is dependent in the case of siliceous igneous and metamorphic rocks chiefly on the physical character of the primary mineral components, whereas in basic igneous rocks and sandstones it is caused to a large degree by colloidal products of rock decomposition.

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WM. A. TAYLOR, Chief

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March 17, 1916

THE RAISIN INDUSTRY.¹

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Office of Horticultural and Pomological Investigations.*

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ORIGIN AND GROWTH OF THE INDUSTRY.

With the exception of very limited quantities produced in Arizona, Utah, and New Mexico, all the raisins grown in the United States are produced in California.

The first introduction of raisin varieties into California was by Col. Agostin Haraszthy. In 1851 he grew muscatels from the seed of imported raisins. On March 25, 1851, he imported the Alexandria (*Muscat of Alexandria*) and in 1861 the Gordo Blanco (muscatel) and Sultana from Spain and the White Corinth and Red Corinth from the Crimea. Another importation of Muscat of Alexandria was made by A. Delmas in 1855 and planted near San Jose, Cal. The first raisins appear to have been produced in the San Bernardino Valley, but the industry soon spread northward. G. G. Briggs, of Davisville, imported muscatel grapes from Spain, while R. G. Blowers, of Woodland, Cal., started a raisin vineyard of Gordo Blanco (muscatel) in 1863 with cuttings received from Col. Haraszthy. The Briggs and Blowers vineyards were the first in the

¹ This bulletin has been prepared for the purpose of answering questions relative to the raisin industry of the United States. The pruning, training, cultural methods, and varieties suitable for raisin purposes, as well as the methods of harvesting and drying the grapes and the curing and processing of the raisins, are described.

State to successfully produce raisins. This was in 1867, but it was not until 1873 that their raisin crops became an important factor in the market, when they amounted to nearly 6,000 boxes. In 1873 Judge J. W. North planted the first Alexandria (*Muscat of*) grapes at Riverside, and three years later raisin-grape growing had become general. R. G. Clark planted Muscats in El Cajon Valley in 1873, but most of the vineyards of that district were not planted until 1884 to 1886. In the fall of 1873, 25 acres of Alexandria were planted in the Eisin vineyards near Fresno, and in 1875 the McPherson brothers made their first plantings near McPherson. The industry grew so that Robert McPherson, the largest grower, became at one time not only the largest packer and dealer in the district but the largest then in the State. In 1876 W. S. Chapman imported material of the best obtainable Muscat grapes for the Central California Colony in Fresno County, which, however, proved to be the same as those planted in 1873. In 1876 and 1877 T. C. White planted the Raisina vineyard with Gordo Blanco (muscatel), and in 1877 and 1878 Miss M. F. Austin planted the same variety at the Hedge Row vineyard. Cuttings of Sultanina were received in 1878 by W. T. Thompson, of Yuba City, Cal., from Elwanger & Barry, Rochester, N. Y., and described by them as the Lady de Coverly, from Constantinople. The so-called Feher Szagos is said to have been found growing in California and was christened by a Hungarian, who claimed to recognize the variety as one he had known in his native land. The Butler vineyard, which was then one of the largest, was planted in 1879. Col. William Forsythe began raisin growing in 1881 or 1882.

In 1873 the entire State of California produced 120,000 pounds of raisins; in 1875, 220,000 pounds; in 1880, 1,500,000 pounds; and in 1885, 9,400,000 pounds. In 1887 Fresno County produced 7,000,000 pounds, and raisin growing was recognized to be its leading industry.

The figures in Table I, taken from the reports of the California State Board of Agriculture and the United States Department of Commerce, showing the California crop and the quantity and value of exports and imports, will prove interesting and serve to show the growth of the industry. As the practice has been not to produce more than enough raisins to supply the demand, the difference between the crop produced and the quantity exported will show the consumption of home-grown raisins in this country. It is also of interest to note, as shown in this table, that in general as the production of raisins in California has increased exports have increased and imports have correspondingly decreased.

TABLE I.—*California raisin crop compared with the quantity and value of exports and imports of raisins in the United States.*

Year.	California crop (pounds).	Exports for fiscal year ending June 30.		Imports for fiscal year ending June 30.	
		Pounds.	Value.	Pounds.	Value.
1885.....	9,400,000	-----	-----	38,319,787	\$2,661,669
1890.....	38,000,000	-----	-----	36,914,330	1,997,103
1895.....	91,000,000	-----	-----	15,921,278	651,420
1900.....	90,000,000	2,415,456	\$139,689	10,309,498	531,124
1905.....	87,000,000	7,054,824	372,087	4,041,689	273,031
1910.....	115,000,000	8,526,114	417,403	5,042,683	296,047
1911.....	120,000,000	18,659,992	1,069,300	2,479,220	237,422
1912.....	185,000,000	19,949,046	1,351,986	3,255,861	295,466
1913.....	130,000,000	28,120,507	1,512,642	2,579,705	241,630
1914.....	182,000,000	14,766,416	997,575	4,554,549	309,511
1915.....	250,000,000	24,845,414	1,718,547	2,808,806	238,958

About 110,000 acres are devoted to raisin growing. Of the 58 counties in California, 11 produce raisins in commercial quantities. The raisin output of the State in 1914 was 182,000,000 pounds. The estimated quantity produced in each county is shown in Table II.

TABLE II.—*Estimated production of raisins in California, by counties, in 1914.*

County.	Crop.	County.	Crop.
	<i>Pounds.</i>		<i>Pounds.</i>
Fresno.....	106,000,000	Yolo.....	2,500,000
Tulare.....	20,000,000	Kern.....	1,600,000
Kings.....	24,000,000	Colusa.....	900,000
Sutter.....	6,000,000	Los Angeles.....	800,000
San Bernardino.....	4,600,000		
San Diego.....	3,200,000	Total.....	182,000,000
Madera.....	2,400,000		

It will be seen from this that Fresno County alone produces nearly 60 per cent of the entire raisin output of the State. It was in 1892 that the California raisin crop first equaled that of Spain. California now produces about three times as many raisins as Spain.

At present the annual consumption of raisins in the United States is less than $1\frac{1}{2}$ pounds per capita. Were we to consume as much as Great Britain, or about 5 pounds per capita, the industry in this country could be quadrupled without causing overproduction.

SOME FLUCTUATIONS IN THE INDUSTRY.

From 1889 to 1893 an average of 5 cents a pound was realized by the raisin growers, and the industry was very profitable. An era of falling prices then began and continued until in 1897 raisins were quoted as low as three-fourths of a cent a pound. Many growers gave up in despair, and thousands of acres of vines were

plowed up. The growers who persisted saw that to succeed they would have to cooperate. In 1898 the California Raisin Growers' Association was founded under the direction of the late M. Theo. Kearney, owner of the largest raisin vineyard in California. In 1903 prices again fell, the association was unable to sell the raisins it had contracted for, and many growers received no returns. As only 30 per cent of the estimated acreage had been signed up, all contracts were returned August 1, 1904, and the association went into the hands of a receiver. Another attempt made in 1904 to organize the growers resulted in the incorporation on May 6, 1905, of the California Raisin Growers' Co., with M. F. Tarpey as president. The company was never well supported by the growers and dissolved after nearly a year's existence.

On November 24, 1911, the California Raisin Exchange, planned by W. R. Nutting, was organized under the California membership association law. Its first object was to map all the vineyards and orchards in the central California fruit district, and its ultimate aim was to maintain an open place of exchange for the sale of raisins and dried fruit.

What was at first styled "The Million Dollar Co." was legally organized on November 15, 1912, as "The California Associated Raisin Co." by the election of 25 trustees and with \$401,000 cash capital, subscribed by growers, which was increased to \$750,000 before April 1, 1913, and has since been increased to \$1,050,000. It was incorporated on April 1, 1913, for \$1,500,000. In 1914 6,500 growers contracted their crops with it.

Active effort is being made by this organization to bring raisins into more general use.

On April 30, 1915, an entire carload of raisin bread was distributed free at the Panama-Pacific Exposition from the Pure Food and California Buildings.

A distinguishing feature of the raisin industry is that the vineyards consist mainly of individual vineyards of 10 to 50 acres each, although there are some which contain from 100 to several hundred acres, and a few from 500 to 1,000 acres or more each. It will not be amiss to state that a peculiar relationship has for some time existed in the raisin-producing section between the grapes used for raisins and those used for wine and brandy. For example, Alexandria, the leading raisin grape, always has a heavy second crop of grapes, which is practically all made into wine and brandy, the raisins being cured from the first-crop grapes. It is also the endeavor to cure only sufficient raisins to supply the demand, and the grapes not required for raisins are made into wines and brandies. The product of about 110,000 acres is at present converted into raisins to meet the demand for about 182,000,000 pounds per annum.

Many changes have occurred since raisin growing became an industry in Orange County, and Fresno has become the center of the industry, as the conditions there are exceptionally suited to the growing and curing of raisins.

RAISIN-VINEYARD SOIL.

Raisin-vineyard soils vary considerably, the deep-gray alluvial bottom land being considered the best. In this connection the mechanical analysis of the soil in the department experiment vineyard near Fresno, made by the Bureau of Soils, and shown in Table III, will prove interesting.

TABLE III.—*Analysis of the soil of the Fresno Experimental Vineyard at Fresno, Cal.*

Description and depth of soil.	Mechanical constituents (per cent).						
	Coarse gravel.	Fine gravel (2 to 1 mm.).	Coarse sand (1 to 0.5 mm.).	Medium sand (0.5 to 0.25 mm.).	Fine sand (0.25 to 0.1 mm.).	Very fine sand (0.1 to 0.05 mm.).	Silt (0.05 to 0.005 mm.). and Clay (0.005 mm. and smaller).
Brown sandy loam:							
0 to 12 inches.....	0.58	1.2	9.8	6.7	18.4	12.0	33.2
12 to 24 inches.....	.71	.9	9.1	6.9	17.8	12.3	32.5
Sandy loam:							
24 to 36 inches.....	.51	.6	8.3	7.8	19.9	12.9	27.1
36 to 48 inches.....	.35	.9	8.8	6.0	13.7	13.1	36.3
Free sandy loam:							
48 to 60 inches.....	.11	1.2	14.2	8.6	22.4	15.7	26.5

Of this type of soil about 75,000 acres near Fresno, 6,000 near Stockton, and about 265,000 in the Sacramento Valley have been mapped by the Bureau of Soils. For a further description of the soils, see Bureau of Plant Industry Bulletin 172 and the surveys of the Bureau of Soils.

PREPARATION OF SOILS.

In the raisin-producing sections of California the country is naturally so level that not much grading is necessary. After the land has been leveled where needed it should be well prepared. If virgin soil is to be used, it will allow the field to be put in better shape if a crop of grain is grown on it the season before planting. After being plowed and subsoiled, it should be thoroughly harrowed and clod-crushed with a drag or roller. In the early stages of the industry most of the vines were planted 7 feet apart each way (Pl. I, fig. 1). The tendency now is to plant farther apart, some planting 8 feet apart each way (Pl. I, fig. 2), others 6 by 10 feet, 9 by 9 feet, 8 by 10 feet (Pl. I, fig. 3), or even wider distances apart. Trellises are the exception (Pl. II, fig. 1); usually stakes are simply used to support

the vines (Pl. II, fig. 2). This enables the growers to plow and cultivate lengthwise and crosswise. Of late years, since the proper method of pruning Sultanina has become better known, there is a tendency toward trellising. The vineyards are plowed twice annually. In the first plowing the soil is thrown away from the vines (Pl. I, fig. 3), and in the second it is thrown up to them again (Pl. I, fig. 1). Frequent cultivations are given early in the season, all culture being abandoned after the spring rains are over.

Crops can be grown without irrigation, but it has been practiced largely because it increases the size of the fruit and therefore also increases the yield. Trouble has been experienced in some localities on account of the lands becoming waterlogged from irrigation.

PRUNING METHODS IN RAISIN VINEYARDS.

Three methods of pruning are practiced with raisin varieties in this country. These are spur, cane, and spurring laterals on canes, the methods used differing with the varieties. All grape-pruning systems have, however, the one underlying principle that the grape usually bears its fruit on shoots from wood of the previous year's growth. The pruning should, therefore, be such as to renew the wood at a given point from year to year, thereby regulating its production and keeping the plant thoroughly shaped and under constant control.¹



FIG. 1.—A grapevine pruned to spurs.

THE SPUR, STOOL, OR SHORT PRUNING SYSTEM.

The simplest and cheapest method and the one extensively used in California with the stockier varieties of *Vinifera* grapes is the spur system, otherwise known as the stool or short pruning system. By this method the body of the vine is grown to the desired height and shoots are permitted to grow from only the two uppermost buds. The two resulting canes are cut back in the winter to spurs of two eyes each. The following year these spurs are allowed to produce growth. The resulting canes are again cut back to spurs and all of them allowed to remain if the vine is strong enough. Thus the vine under ordinary conditions at the beginning of the fifth year consists of a trunk from which spring four or five arms, on each of which a cane has been cut back to a spur (fig. 1 and Pl. II, fig. 3). When the vine is pruned the following winter all, or nearly all, the outer canes that have grown from the spurs are entirely removed. The

¹ For full information on the pruning and training of vines, see *Farmers' Bulletin* No. 471, entitled "Grape Propagation, Pruning, and Training."

spurs of the last season are cut off just outside the inner canes, which are cut back to spurs, the pruning each winter after this being done to promote a regular system of spur renewal. As the vines become older and stronger and can stand more cropping, more spurs are left to increase the fruiting capacity of the plant. In course of time the arms of the respective spurs are renewed and entirely new arms and spurs are grown. The head of the vine should be kept well balanced and given a globular form if possible. Some varieties on which the lower eyes are not sufficiently productive may be improved by increasing the length of the spurs and the number of eyes, leaving four or even five eyes to a spur, according to the variety of the vine.

THE LONG, OR CANE, PRUNING SYSTEM.

The long, or cane, pruning system is also in general use in California. When vines are trained according to this system the fruit is borne on canes which are tied to a stake, the spurs which are left to grow from them producing canes for the following year. In pruning, the canes which fruited the previous year as well as the arms on which they grew are entirely removed, the canes produced from the spurs left the previous year furnishing the fruiting canes and spurs needed (fig. 2). In this manner the head of the vine is renewed from year to year, and as the plants grow older and stronger the fruiting capacity is increased by leaving more canes and spurs.

The Sultanina bears well only when pruned to long canes. Provision should therefore be made for the growth of new canes from the stump, to furnish bearing canes for the following years. This is accomplished in pruning by leaving short spurs of one or two buds on the main stump from which to grow the canes. Frequently, however, the spurs are so shaded by the foliage on the fruiting canes that they do not always produce vigorous wood and often fail to grow. To remedy this, two methods are employed; namely, (1) bending and tying the fruiting canes to form a circle (fig. 3), and (2) training the fruiting canes on horizontal trellises. The first method diminishes the tendency of the sap to go to the end of the fruiting canes and causes a greater number of shoots to start on the lower parts of them. These shoots are not so strong, but are more fruitful. Another result of the bending of the canes is that the sap pressure starts strong



FIG. 2.—A grapevine pruned to canes.

shoots from the spurs left for the purpose. These shoots are used as fruiting canes the following year, new spurs being left to grow canes for the next year. In the second method the pruning is the same and the same objects are accomplished, but a trellis is used on which the fruiting canes are placed in a horizontal position and tied to the trellis wires (Pl. II, fig. 1). The Sultanina variety also has a tendency to send out suckers, water sprouts, and sterile shoots. For that reason

the vines should be carefully gone over several times after the young shoots start, to remove undesirable growths.

RAISIN VARIETIES.

The raisin varieties are all *Viniferas*, therefore they are not resistant to phylloxera, and for this reason they should be grown on phylloxera-resistant stocks to make permanent, durable vineyards.

The principal raisin variety grown is the Alexandria (Pl. III). This has numerous synonyms, but is so well known in this country as Alexandria that no other names need now be given.

Ripens midseason. Color yellowish green; when fully ripe, flushed with amber. Cluster straggling, long, loose, and never compact even when perfect. Stem long, reddish brown; pedicel thick, warty, yellowish, one-half inch long. Berry large, five-eighths by 1 inch long, tapering toward pedicel, sometimes slightly flattened at apex; surface smooth, yellowish green; bloom white; adherence excellent. Skin tough and thick. Flesh meaty, firm, fairly juicy. Seeds one to four, long, reddish brown. Flavor spicy, fruity, and rich. Vine robust, with small-furrowed, light-yellow wood, dotted with black. Leaves five-lobed, medium size, thick, leathery, smooth, rather deeply serrated, slightly elongated, light green, slightly glossy above, gray yellowish green underneath; veins thin, red at base; leaf stem longer than midrib of leaf; petiolar sinus open.

This is the most important raisin variety. It is also a very important shipping grape, as it carries well, looks well, and many ad-

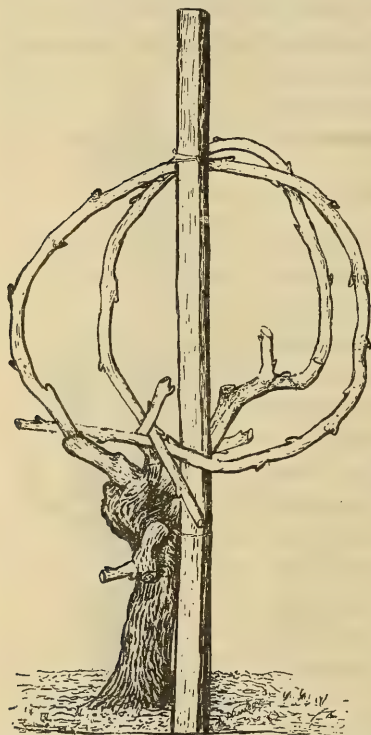


FIG. 3.—A grapevine pruned to long canes, the canes afterwards being bent in a circle on the support.



FIG. 1.—CROSS PLOWING A MUSCAT VINEYARD.



FIG. 2.—A MUSCAT VINEYARD READY FOR PLOWING.



FIG. 3.—A SULTANINA VINEYARD AFTER PLOWING.



FIG. 1.—PRUNED SULTANINA VINES ON TRELLISES.



FIG. 2.—PRUNING SULTANINA VINES TO CANES.

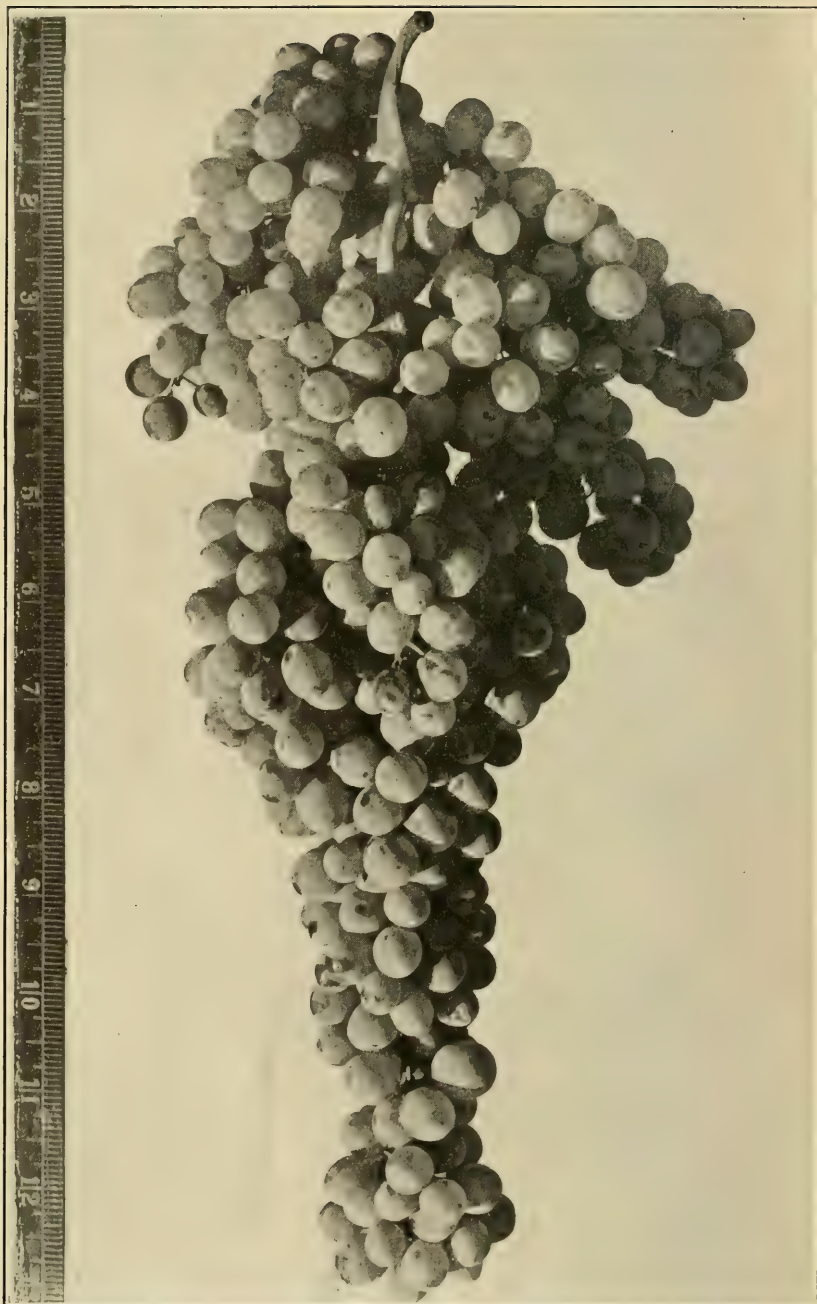


FIG. 3.—PRUNING MUSCAT VINES TO SPURS.



A CLUSTER OF ALEXANDRIA (MUSCAT OF ALEXANDRIA) GRAPES.

(Two-thirds natural size.)



A CLUSTER OF SULTANINA (ERRONEOUSLY CALLED THOMPSON SEEDLESS) GRAPES.

mire its peculiar flavor. It seems to have been first cultivated by the Arabs.

The vine is fairly productive, but does not always set well. The laterals produce a heavy second crop and sometimes a third crop. The vine should be pruned to the spur system (fig. 1 and Pl. I, fig. 1). Tests made of this variety grafted on a number of resistant stocks so far show good congeniality to exist between it and *Riparia* × *Rupestris* 3309, *Riparia* × *Rupestris* 101, Dog Ridge, *Riparia* × *Rupestris* 101-14, and *Berlandieri* × *Riparia* 420-A, in the order named.

The muscatel Gordo Blanco, which has also been grown to a considerable extent in this country, resembles the Alexandria, differing from it principally in having a round berry and clusters more compact.

The Huasco and White Hanepoot are practically identical with Alexandria.

The Malaga and Feher Szagos (both wrongly named), which have been desiccated to a considerable extent in the past, are not now much used. Other large-berried varieties that have been dried in limited quantities will never figure commercially, it is thought, and for this reason are not mentioned.

Next to Alexandria, the Sultanina (Pl. IV and Pl. V, fig. 1; synonyms, *Sultanieh*, *Ezkerdeksis*, *Tchekirdeksis*, *Kechmich*, *jaune a grains oblongs*, *Conforogo*, etc., and erroneously, *Thompson's Seedless*—from which the seedless raisins are cured) is most important. It ripens about midseason. Color light yellowish green, flushed when fully ripe. Cluster long, fairly loose, and often fairly compact, large, from 6 to 16 inches long; stem $1\frac{1}{2}$ to 2 inches long, medium size, wiry. Pedicel light green, one-third inch long, slender and warty. Berry oblong, above medium size, five-eighths to three-fourths by three-fourths to 1 inch; adherence good; apex large, black, protruding, with prominent oriole ring. Surface smooth, light yellowish green; bloom white; glossy. Skin medium thick, tough. Flesh fairly meaty, moderately firm, fairly juicy. Flavor sweet, with delicious acidity. An excellent dessert, table, shipping, wine, and raisin grape. Vine a strong, long grower, light brown, long jointed, slender; canes long. Leaf thin, light, bright green above, lighter underneath, smooth and shiny, sharply serrated. An extremely popular and most valuable grape. Should be pruned to canes and trained as stated on pages 7 and 8. (See fig. 3 and Pl. II, fig. 1.) So far, it has shown good congeniality on the following stocks, in the order named: *Riparia* × *Rupestris* 3309; Dog Ridge, *Aramon* × *Rupestris* Ganzin No. 1, *Riparia* × *Rupestris* 101, *Lenoir*, *Solonis* × *Riparia* 1616.

The Sultanina Rosea, a rose-colored variety of Sultanina, is attracting some attention of late years. It should be pruned and trained like Sultanina.

The Sultana has also been grown to some extent, and although a valuable grape that thrives in a number of localities and under a number of diverse conditions, no large vineyards of it are yet to be found in this country.

Panariti (Pl. VI; synonyms, *Corinthe Rose* and *Passereta rosada*) ripens very early. Color amber. Clusters very long, almost cylindrical, but tapering, frequently enlarged toward end of cluster, often shouldered, straggling, loose; stem $1\frac{1}{2}$ to 2 inches long, of medium size, soft, and fleshy. Pedicel light green, one-fourth to one-third inch, extremely slender. Berry round, very small, not averaging much over one-fourth inch in diameter; surface smooth. Color amber, with whitish bloom. Skin thin. Flesh white, soft, juicy. First crop seedless. Flavor rich and sweet, with characteristic currant flavor. Vine vigorous, stocky, but spreading. Canes thick, long, light brownish, smooth, striped, with internodes 3 to 4 inches long. Leaf irregular, five-lobed; upper side rather dark green with lighter green veins; araneous; under side lighter, slightly whitish with yellowish down; indentations small, angular, rounded, higher than broad; petiolar sinus slightly rounded, irregular, rather small. Does well pruned to spurs and short canes (fig. 2 and Pl. II, fig. 2). To get regular crops, annular incision should probably be practiced. Tests of the variety grafted on a number of resistant stocks have so far shown good congeniality to exist between it and Rupestris St. George, Mourvedre $\times$ Rupestris 1202, Aramon $\times$ Rupestris Ganzin No. 1, Riparia $\times$ Rupestris 3309, Salt Creek, and Dog Ridge, in the order named.

The White Currant (synonyms, *Kischmisch*, *Passerina*, *Passera*, *Passereta*, *Szemer*, *Szem*, and *Corinthusi Aproxzemer*) and the Black Currant (synonyms, *Corinthe Noir*, *Currant grape*, *Patras Currant*, *Zante*, *Raisin de Corance*) are very similar to the Panariti, differing materially from it only in color.

Currants have not so far been grown to any great extent in this country, not because they will not thrive here, but no one has engaged in their culture seriously enough to determine the right way to grow, prune, and train them. Vines of the white variety are scattered about in California, but there are no extensive plantings. These produce a beautiful, semitransparent, seedless raisin of good flavor, but inferior to the Black Zante grown on the mainland of Greece. The Department of Agriculture for some years has made experiments in the growing of currant varieties of grapes on different resistant stocks and practiced on them different methods of pruning and training, with very gratifying results, and strong hopes are entertained of starting and developing this special line of the raisin industry. There seems to be no reason why this country should not

produce the 35,356,000 pounds, or \$1,206,000 worth, of currants it has for 10 years been annually importing.

CLIMATIC CONDITIONS IN THE RAISIN BELT.

So ideal are the climatic conditions for the raisin industry, and they have such an important influence in drying raisins and other fruits, that the temperature and rainfall records of Fresno and vicinity, furnished by the Weather Bureau, are herewith given. Table IV shows the seasonal rainfall (in inches) for 15 years.

TABLE IV.—*Rainfall at Fresno, Cal., from June to November, 1900 to 1914.*

Year.	June.	July.	Aug.	Sept.	Oct.	Nov.
1900.....	Trace.	Trace.	0	0.16	0.33	4.61
1901.....	Trace.	Trace.	Trace.	.59	.56	.86
1902.....	Trace.	0	Trace.	0	.42	2.25
1903.....	Trace.	0	0	0	0	.68
1904.....	0	0	0	1.78	3.21	.08
1905.....	0	0	0	Trace.	0	.96
1906.....	Trace.	Trace.	0	Trace.	0	.73
1907.....	.24	0	Trace.	Trace.	1.08	0
1908.....	0	.01	0	.15	.02	.66
1909.....	.80	0	0	0	.72	2.79
1910.....	Trace.	Trace.	0	1	.45	.24
1911.....	Trace.	Trace.	0	.01	.09	.17
1912.....	Trace.	Trace.	0	.10	.01	.85
1913.....	.10	.33	Trace.	Trace.	Trace.	1.86
1914.....	.23	Trace.	Trace.	.22	.26	.11

As to temperature it is noted that in the hottest time of the summer the mercury has risen as high as 115° F. in the shade. The average of the highest daily temperatures is about 100° during July and about 98° in August, while the average of the day and night temperatures for the same months is about 82°. The nights are always much cooler than the days. The coldest weather in winter is 17° F. (above zero). The summers are rainless, and the nights are so free from dew or moisture that a piece of tissue paper, after lying out all night, is crisp and stiff the next morning, without a particle of moisture showing.

The rainfall averages 10 inches a year. The principal rains occur in January and February, with some showers in October. Frequently it rains enough in November to cause considerable damage to partly dried raisins or grapes.

HARVESTING AND PREPARING THE CROP.

Drying is the most ancient and primitive of fruit-preserving methods, the dried fruit containing much more nutritive value in proportion to its bulk than fresh fruit. In the raisin districts of this country grapes are ripe by the middle of August, the season often lasting into November. The average time necessary for drying and curing a tray of raisins is about three weeks, depending on the

weather, the earliest picked grapes drying in 10 days and the later ones often taking four weeks or more.

The method of drying is very simple. The bunches are cut from the vines and placed in shallow trays 2 feet wide, 3 feet long, and 1 inch high (Pl. V, figs. 1 and 2), on which the grapes are allowed to sun-dry, being turned from time to time by simply placing an empty tray upside down on the full one and then turning both over and taking off the top tray. After the raisins are dried they are stored away until they are packed and prepared for shipment. Some of the larger growers, in order not to run so much risk in drying on account of rain, and also to enable them to handle the crop fast enough, have curing houses, where the curing is finished after having been partially done outside.

DIPPING AND SCALDING RAISINS.

The operation of dipping and scalding is designed to accomplish several purposes, namely, to cleanse the fruit, to hasten its drying, and to give the dried fruit a lighter color. In dipping and drying, the fruit, immediately after being cut from the vines, is either dipped in clear water to first rinse it of particles of dust and other foreign matter, or it is taken direct to the scalding and immersed in a boiling alkaline mixture called "legia" (lye) until the grapes show an almost imperceptible cracking of the skin, the operation consuming perhaps from one-fourth to one-half of a minute. This dipping calls for skill on the part of the operator, the duration of the immersion depending on the strength and temperature of the mixture and the condition of the fruit. Desiccation follows the scalding process, which is accomplished on trays (Pl. VII, fig. 1) in the sun, the same as undipped raisins cured entirely by solar heat (Pl. VII, fig. 2). On account of the scald they cure rapidly, and the fruit is also often of lighter color when cured. The following formula has been used at Woodland, Yolo County, for Sultana and Sultanina grapes:

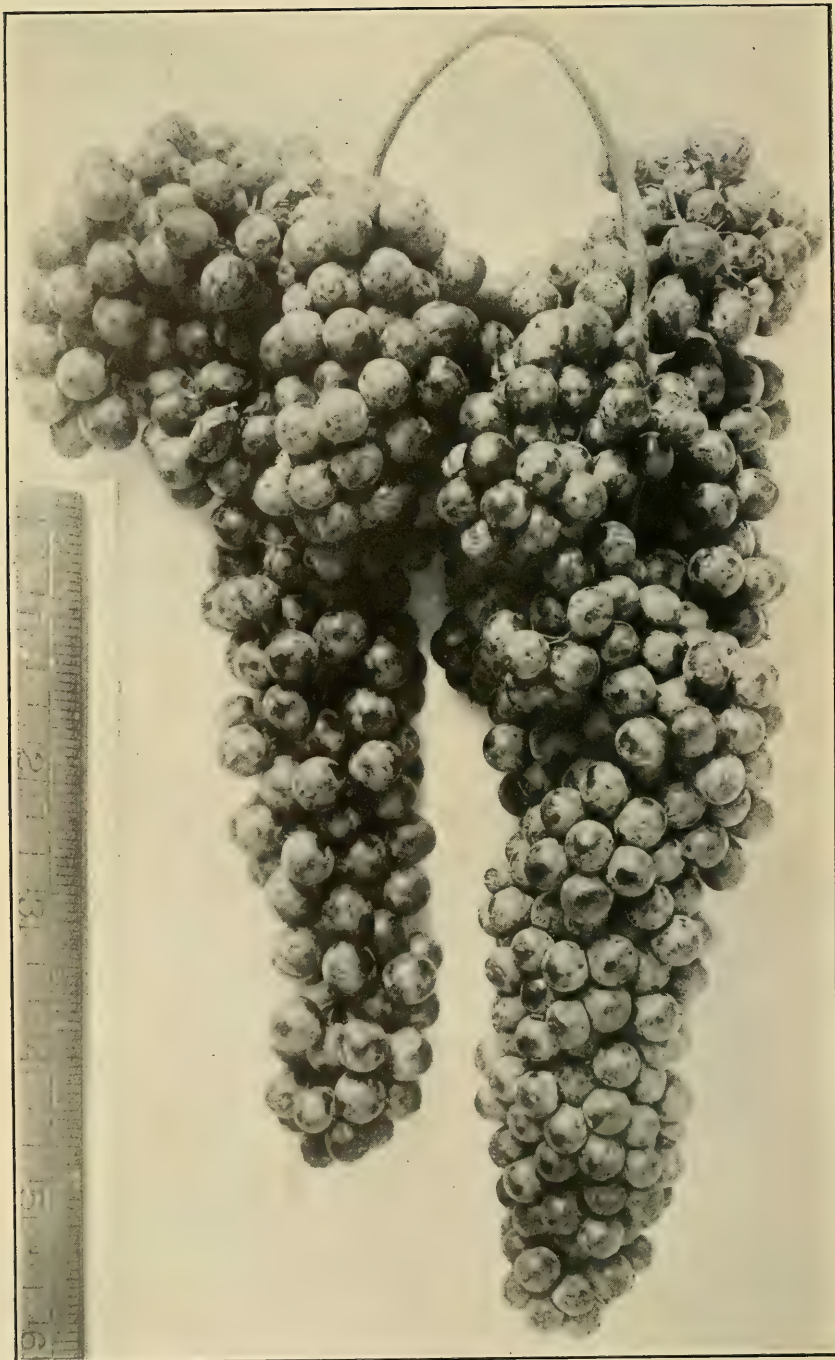
Thirty pounds of English bicarbonate of soda are boiled in 30 gallons of water until dissolved, to which are added 70 gallons of water and approximately one teacupful of genuine olive oil. This mixture is for grapes containing 25 per cent of sugar; should their sugar content be less, more bicarbonate of soda is added. The bicarbonate of soda must be sufficiently strong to remove the bloom of the grape and open the pores of the skin to facilitate drying. The cup of olive oil added forms a thin film on the surface of the solution. This film is preserved while dipping by adding an occasional teaspoonful of oil, the mixture being kept sufficiently warm so that the oil dissolves perfectly and spreads evenly over the surface. Three-fourths of a gallon of olive oil will be sufficient to dip 5 tons of grapes in the mixture as given here. When the solution gets dirty it is renewed.



FIG. 1.—PICKING AND DRYING SULTANINA GRAPES.



FIG. 2.—PICKING AND DRYING MUSCAT GRAPES.



A COMPOUND CLUSTER OF PANARITI GRAPES.

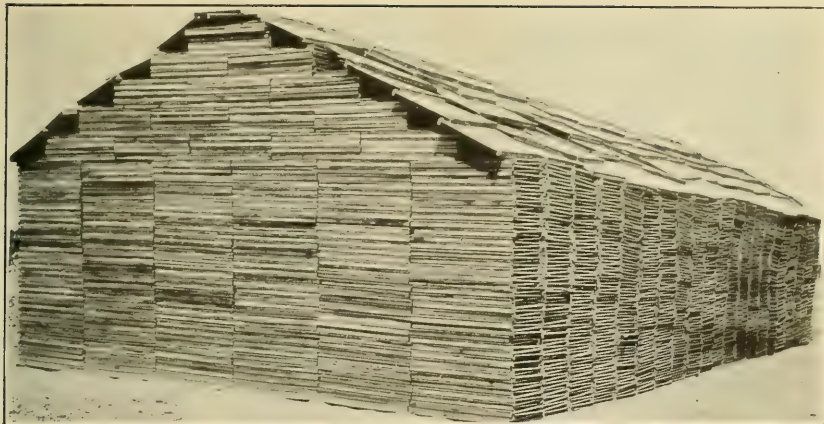


FIG. 1.—A STACK OF RAISIN TRAYS.



FIG. 2.—PART OF A FIELD OF 11 ACRES OF RAISINS CURING ON TRAYS.



FIG. 3.—HAULING AND STORING RAISINS IN SWEAT BOXES.

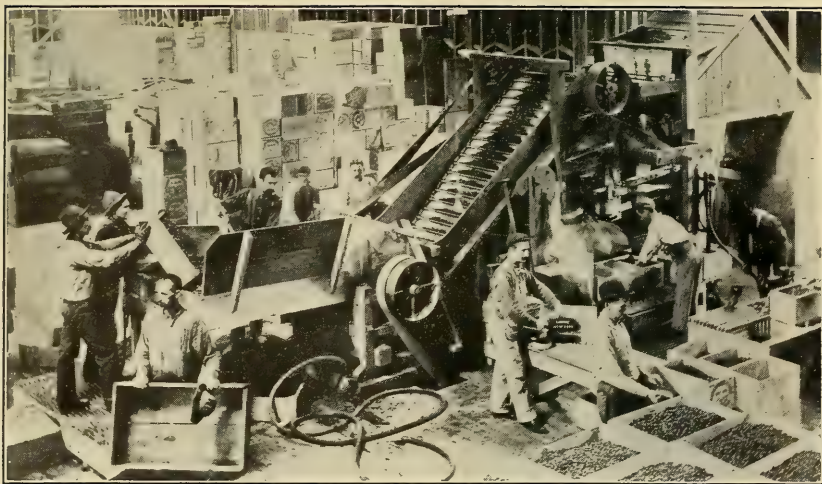


FIG. 1.—STEMMING AND CLEANING RAISINS.



FIG. 2.—RAISIN SEEDERS AND PROCESSERS.



FIG. 3.—A RAISIN SEEDING AND PACKING ESTABLISHMENT.



FIG. 4.—AN UNDERGROUND RAISIN CARRIER.



FIG. 1.—PACKING LAYER RAISINS.



FIG. 2.—PACKING SEEDED RAISINS IN CARTONS.



The following formula has been used for Sultana and Sultanina grapes at Fresno:

Fifteen pounds of "Greenbank's 98-per cent lye" are boiled in 100 gallons of water. This mixture is for grapes containing 25 per cent of sugar. Should their sugar content be less, enough lye is added to remove the bloom and open the pores of the skin of the grapes. After dipping, the grapes are spread on trays and sulphured for 1 to 1½ hours. Observation will show whether it may be necessary to vary this formula a trifle to suit conditions of ripeness and influence of temperature. The length of time required for dipping is ascertained by experience, and differs with the strength of the lye, the heat of the solution, and the thickness of the skins of the grapes.

PACKING RAISINS.¹

The raisins as received at the packing house are weighed and the loose raisins and those that are to be shipped as dried grapes are immediately run through a stemmer and grader (Pl. VIII, fig. 1), which stems, cleans, and assorts the raisins into three or four different grades, after which they are packed and shipped to various parts of the country, some also being exported. Those producing cluster or layer raisins (if they have not already been equalized) are first stored in the equalizing rooms (Pl. VII, fig. 3). In these rooms the sweat boxes, filled with layers of new raisins, are stacked and left usually from 10 to 30 days, or long enough for the overdried berries to absorb moisture from the underdried ones. This sweating also properly softens and toughens the stems, which prevents their breaking and enables them to hold the berries better. In California, where the climate is so dry, no first-class pack could be made without thus first equalizing the raisins. After having been equalized the raisins are taken out, assorted into the different grades, and placed in trays holding 5 pounds each (Pl. IX, fig. 1). The trays of the same grades are then pressed and stacked away in piles ready for packing.

Pressing the raisins so they look well and so none are burst open is work requiring experience and good judgment. It takes four pressed trays to fill a 20-pound box. The loose raisins that have dropped from the cluster through handling before they were equalized are also graded, the largest, of course, making the choicest pack.

CLASSES OF RAISINS.

Previous to the consolidated organization of the packers the three best grades of raisins on the stems were known as "Imperial," "Dehesia," and "Fancy Clusters," respectively. The California Raisin Growers' Association established classification and grades similar to

¹ Department Bulletin No. 235. "Control of Dried-Fruit Insects in California."

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BULLETIN No. 350

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THE UTILIZATION OF CHERRY BY-PRODUCTS.

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INTRODUCTION.

The rapid development of the fruit-packing industry in the United States within recent years has had a tendency to direct the attention of packers to the large accumulations of by-products which at present are valueless because of their lack of utilization. The nature of these waste products differs, according to the fruit from which they result. In most cases some portion of the fruit is discarded because it has no further use. Often it is the exterior portion, but in many cases, especially with fruits which require pitting, the waste products consist of pits or seeds which must be removed before canning.

In previous publications of the Department of Agriculture¹ attention has been called to the enormous quantities of raisin seeds and peach and apricot pits which may be made to yield valuable commercial products, and already some manufacturers are turning their attention to these waste products with a view to their profitable utilization.

More recently the attention of the writer has been called by fruit packers to the waste which results from the cherry-packing industry of the North Atlantic, North-Central, and Western States. This is

¹ Rabak, Frank. Peach, apricot, and prune kernels as by-products of the fruit industry of the United States. U. S. Dept. Agr., Bur. Plant Indus. Bul. 133, 34 p., 1908.

— The utilization of waste raisin seeds. U. S. Dept. Agr., Bur. Plant Indus. Bul. 276, 36 p., 3 fig., 1913.

material which has not only been discarded as valueless, but has actually been a source of expense, due to charges for hauling it away.

New York, Michigan, Wisconsin, and California produce the bulk of the cherries grown for canning purposes, and in preparing the fruit for canning large quantities of pits and juice accumulate.

RELATION OF THE CHERRY TO SWEET AND BITTER ALMONDS AND ALLIED PLANTS.

The cherry belongs to the natural order Drupaceæ, which includes a number of our most important fruits, such as peaches, apricots, and prunes. It is a native of Asia Minor and has been introduced into Europe and the United States.

The fruit of the red sour cherry furnished the material for the following investigation, since it is mostly the fruit of this variety which is pitted for commercial use. The red sour cherry is designated botanically as *Prunus cerasus* L. Among the principal varieties grown commercially are the Montmorency Ordinaire, the Richmond, and the English Morello, the first named being the most important variety and producing the bulk of the fruit grown.

The peach, known botanically as *Amygdalus persica* L., the apricot, *Amygdalus armeniaca* L., and the prune, *Prunus domestica* L., are closely related to the cherry, as are also the sweet almond, *Amygdalus communis dulcis* DC. and the bitter almond, *Amygdalus communis amara* DC. All of these species, including the cherry, produce drupaceous fruits which, although of somewhat different sizes and shapes, possess the same general characteristics.

The kernels of both the sweet and bitter almonds yield products of commercial value, as do also the kernels of the peach, apricot, and prune. From the standpoint of chemical composition the kernels of these various species, and also of the cherry, are for the most part identical. All consist principally of a fatty oil and protein, with smaller quantities of sugar, mucilage, and the glucosid amygdalin.

It is generally known that bitter almonds yield two important commercial products, namely, fixed oil and volatile oil. The fixed oil is obtained from the kernels by expression, while the volatile oil is the result of a chemical process induced by the action of the enzym emulsin upon the glucosid amygdalin. It has been found that peach, apricot, and prune kernels also yield oils very similar to those obtained from bitter almonds.¹ The present investigation has shown that cherry kernels likewise are capable of yielding similar oils.

COMMERCIAL IMPORTANCE OF CHERRIES.

As has been stated, the pitting and canning of cherries is restricted almost entirely to the red sour cherries. A variety of sweet cherry,

¹ Rabak, Frank, op. cit., 1908.

the Napoleon (syn., *Royal Ann*), is cultivated extensively in California, and to a lesser degree in Oregon and Washington. This is used partly to supply the demand for the bottled cherries of commerce known as the maraschino cherries. Most of the cherries used for this purpose, however, are imported from Spain and Italy. These are pitted and bottled in the United States and constitute an important article of commerce. A large accumulation of pits results from the packing of the imported cherries, and the present investigation has been extended to include this waste product, as well as the waste resulting from domestic cherries.

The extent of the cherry-packing industry is indicated in the agricultural statistics of the States mentioned. According to the Thirteenth Census of the United States, the quantity of cherries grown in New York in 1909 was 271,597 bushels, in Michigan 338,945 bushels, and in Wisconsin 81,340 bushels, making a total of 691,882 bushels, or 20,756 tons. The quantity grown at the present time is doubtless considerably in excess of these figures. Approximately 80 per cent. of the crop is canned, which is equivalent to 553,506 bushels, or 16,605 tons. The total output of the California orchards in 1909 was 501,013 bushels, or about 15,000 tons.

Accurate figures showing the total quantity of cherries pitted annually are not available. Approximate figures, however, were obtained by correspondence and by consultation with the principal packers in the various canning sections. The average annual importation of maraschino cherries from Italy and Spain, as calculated from the quantity of pits which result, is about 2,500 tons.

ACCUMULATION AND DISPOSAL OF BY-PRODUCTS.

Two by-products of the cherry industry, the pits and the juice, are at present entirely wasted. From the standpoint of commercial utilization the pits constitute the larger and more important of these waste products.

It has been estimated that about 15 per cent of the cherries consists of pits. Since definite information regarding the total quantity of cherries pitted was unavailable and since the quantity pitted is dependent entirely upon the crop of each season, only approximate figures regarding the total output of waste pits are presented.

The figures given were obtained by interviews and correspondence with 23 packers in New York, 6 in Michigan, and 3 in California, who estimated the quantity of waste pits in 1914 as follows: New York, 800 tons; Michigan, 200 tons; and California, 400 tons. The total output was probably somewhat greater, as several packers failed to supply estimates. Wisconsin is rapidly increasing the acreage of cherries and, as predicted by growers, will probably produce several

hundred tons annually. Smaller quantities are also available in New Jersey and Pennsylvania.

From the figures given by the packers it would appear that 1,600 tons is a conservative estimate for the total quantity of cherry pits that become available each year. This quantity will most likely increase, owing to the increasing acreage.

The cherry juice which results from this industry accumulates in very large quantities. According to one prominent packer the quantity of juice is estimated at about 70 gallons per ton of cherries. Calculated on the quantity of cherries pitted, it is estimated that the approximate output of juice is 112,000 gallons annually. At the present time this by-product is entirely wasted, although several packers have attempted to find some use for it.

The pits of the imported cherries have also been discarded, and often at considerable expense. About 650 tons may be considered as the annual output of this waste.

The writer was informed by nearly all the packers consulted that much thought has been given to a possible utilization of the large quantities of waste material and that great benefit would result and an added stimulus be given to this important branch of the fruit industry if a profitable utilization of the waste products could be accomplished.

Actuated, therefore, by the requests of many packers and by actual observation of the large quantities of pits and juice which accumulate at the packing plants, the investigation herein described was undertaken.

COMMERCIAL PRODUCTS OBTAINABLE FROM CHERRY PITS.

Because of the relationship of the cherry to the sweet and bitter almonds and to the peach, apricot, and prune, it was not unreasonable to suppose that products could be obtained from the pits of the cherry similar to those obtained from the other fruits mentioned. Fixed and volatile oils are at present manufactured from almonds and from peach and apricot kernels. The oils from these various kernels are practically identical in character and may be used for similar purposes; in fact, they are so nearly alike that much of the almond oil of commerce has been obtained from peach and apricot kernels. The composition of the kernels from cherry pits is such as to admit of the extraction of fixed and volatile oils, both possessing the general characteristics of almond oils.

The pits of the imported cherries present a somewhat different problem, due to the treatment of the fruit before importation. At the time these cherries are picked the kernels contain presumably the same constituents as the domestic cherries. The composition is nota-

bly altered, however, by the processes involved in packing. Briefly, the fruit receives the following treatment: When ripe it is picked and placed in trays, and then subjected to the bleaching action of sulphur dioxid, which changes the red color of the fruit to a pale yellow. After bleaching, it is packed in a 3 per cent salt brine in casks having a capacity of 350 pounds, in which containers it is imported, the cherries remaining in the brine for about four months.

In bottling the cherries the first step consists in washing them with successive portions of fresh water until all the salt is removed. The cherries are then pitted by hand, women being employed for this operation. After pitting, the fruit is packed in the bottles by hand, and hot sirup is poured over it, together with an artificial red coloring matter and a small quantity of bitter-almond oil, the latter being added to impart the cherry flavor.

Upon examining the kernels of the pits which were removed from these cherries before bottling, it was observed that when the kernels were crushed in the mouth no volatile oil was apparent. It is quite probable that the action of the sulphur dioxid and the salt brine exerts a detrimental influence upon the glucosid contained in the kernel. The fact that no bitter-almond taste developed was conclusive evidence that the amygdalin had been destroyed or its hydrolysis impaired by the treatment the fruit had received. However, a fixed oil was found to be present in the kernels and its quality was not seriously impaired, as will be shown later.

The juice from the domestic cherries is extremely acid in taste, but after neutralization of the acid considerable sugar was noted. The preparation of alcohol from the waste juice and the possibility of reducing the juice to a sirup were considered. It was thought probable also that by means of some jelling medium the juice might be used for making jelly.

Attention may also be directed to the meal which results after the extraction of the fixed and volatile oils from the pits and kernels. This meal is rich in nutritive constituents and should find a useful outlet in commerce.

Briefly summarizing: A number of products may be obtained from the pits and kernels of cherries and from the juice, which, as will be shown, may prove of commercial importance.

FIXED OIL.

METHODS OF EXTRACTION.

The extraction of a fixed oil from seeds is usually accomplished by one of two methods: The use of hydraulic pressure or of volatile solvents. Both methods have a general application.

Volatile solvents are used in many instances, especially in the case of seeds which are more or less deficient in oil. In all cases the sol-

vents used are such as will readily dissolve the oil. Among those employed are gasoline, ether, benzene, petroleum ether, chloroform, carbon bisulphid, and carbon tetrachlorid. Apparatus of the continuous-extraction type is usually employed. This admits of the recovery of the solvent and minimizes the loss of the solvent. It has been reported that recent improvements in method and apparatus have made this process cheaper than the pressure method. The solvent can be entirely removed from both the oil and the residue. It is also held that by the employment of this process various kinds of material can be treated in the same apparatus. The expense of operating is also said to be less than the pressure method.

The color of oils extracted by solvents is often very dark and it is necessary to remove it, but this can usually be accomplished with no great difficulty.

The solvents perhaps most frequently employed, because of their comparatively low price, are benzene, petroleum ether, gasoline, and carbon tetrachlorid. Of these, carbon tetrachlorid has within recent years become very popular, not only because of its cheapness but because of its noninflammability and less volatile nature, thus reducing the danger from fire and minimizing the loss from evaporation. According to a recent report¹ benzine is used for the extraction of soy-bean oil in a new mill of the South Manchurian Railway Co. at Dairen, this mill having a capacity of 80 tons daily.

Hydraulic pressure is perhaps more universally used than any other method and especially in the case of seeds having a high percentage of oil. This method is not practicable, however, with seeds of low oil content, because the resulting press cake retains a considerable percentage of the oil, and this would materially affect the total yield. Seeds which contain as high as 30 to 50 per cent of oil are best manipulated by extraction under pressure from hot meal or with heated plates, a maximum percentage of oil being thereby obtained. As a general rule, the quality of an oil obtained by hydraulic pressure excels that obtained by volatile solvents, cold pressure producing even better quality than hot pressure. Oils obtained by the pressure method invariably contain less impurities than those extracted by solvents, and therefore require less refining.

Suitable presses for extracting fixed oils are on the market, all embodying the same general principle. Continuous extractors, preferably of copper, are also obtainable from American manufacturers, especially manufacturers of pharmaceutical machinery.

EXTRACTION OF OIL FROM THE PITS BY SOLVENTS.

A quantity of dry pits was finely ground in a drug mill and introduced into a continuous-extraction apparatus fashioned after the

¹ Parlett, H. G. New bean-oil extracting mill at Dairen on the benzine system. *In* Bd. Trade Jour. [London], v. 86, no. 923, p. 385, 1914.

Soxhlet extractor. Extraction was made with ether and continued until the material was completely exhausted. By this process a yield of 8.3 per cent of a pale-brown fixed oil was obtained. By the same process the pits from the imported cherries yielded 4.5 per cent of a deep-brown, rancid-smelling oil.

The crude oil thus obtained was not only deeply colored but possessed a characteristic odor of rancidity, due to the presence of free volatile fatty acids. In order to free the oil of the objectionable color and odor it was subjected to the following refining process: The oil was introduced into a flask and live steam was conducted through the mass until the distillate which contained the free volatile acids possessed no appreciable odor and was no longer acid to litmus. While hot, the oil was separated from the water in the flask by means of a separatory funnel, treated with kaolin (fuller's earth), and the mass filtered through filter paper in a hot filtration funnel. The filtered oil was pale golden yellow in color, with a distinctly nutlike taste and with no suggestion of rancidity.

EXTRACTION OF OIL FROM THE KERNELS BY PRESSURE.

Hydraulic pressure was not found applicable to the pits, because of the low yield of oil. It was necessary, therefore, to crack the pits and remove the kernels. This was accomplished by slowly feeding the pits into a mill having vertical grinding plates set to grind very coarsely, so that a mere cracking of the shells resulted without crushing the kernels. The cracked pits were first put through a round-hole sieve with openings sixteen sixty-fourths of an inch in diameter and then through another sieve with openings of thirteen sixty-fourths of an inch. This removed the coarser parts of the shells. A final separation was made by passing the material through a "wild-oat" sieve with oblong meshes measuring seven sixty-fourths by one-half of an inch. The last screening effected a reasonably complete separation of the kernels from the shells.

It is very important that the mill be fed with a slow, continuous stream of pits, and care must be exercised in order not to crush the kernels, otherwise they are apt to separate into halves and the halves pass through the final sieve. By this process 28 per cent of the pits was found to consist of kernels.

The laboratory press available for the extraction of the oil from the kernels was not entirely adequate for obtaining the best results. A pressure of 2,750 pounds to the square inch was applied to the finely ground kernels, the expression being conducted in the cold. A yield of 21 per cent of a pale golden yellow oil, with a pleasant nutlike odor and taste, was thus obtained. With a commercial hydraulic press of the latest type, equipped for hot expression, a much higher yield would undoubtedly result. Working on a commercial scale

with an efficient hydraulic press or oil expeller, a yield of at least 30 per cent of oil should be obtained.

For the purpose of comparing the yield and general characteristics of the oils obtained from cherry kernels by solvent and by expression with oils from related kernels, Table I was compiled.

TABLE I.—*Yield and physical properties of crude and refined cherry oils compared with other related oils.*

Source of oil.	Yield of oil.	Specific gravity at 23° C.	Index of refraction at 23° C.	Congeealing point.	Color.	Odor.	Taste.
Cherry pits (red sour cherries):							
Crude.....	P. ct. 8.3	0.9204	1.4697	Turbid at -8° C.; almost solid at -12° C.	Pale brown...	Slightly rancid	Slightly acid, fatty, slightly bitter.
Refined.....		.9171	1.4700	Turbid at -8° C.; nearly solid at -15° C.	Pale golden yellow.	Bland, fatty...	Bland, fatty, nutlike.
Cherry kernels (red sour cherries).	132	.9150	1.4727	Turbid at -13° C.; semisolid at -18° C.	Pale golden...	Pleasant, nutlike.	Bland, nutty, agreeable.
Cherry pits (imported cherries):							
Crude.....	4.5	.9302	1.4582	Semisolid at -11° C.	Deep brown...	Fatty, slightly rancid.	Fatty, slightly acid.
Refined.....		.9276	1.4790	Semisolid at -16° C.	Pale brown...	Bland, fatty...	Bland, fatty.
Cherry kernels (imported cherries).	150	.9156	1.4775	do.....	Deep straw...	Agreeable, fatty.	Fatty and nutlike.
Peach kernels ² .	39.5	.9166	.....	Solidifying point below -20° C. ⁵	Yellowish....	Fatty, nearly odorless.	Bland, fatty, nutty.
Apricot kernels. ³	40	.9168	1.4712	-20° C. ⁶	Straw colored.	Slightly fatty, nearly odorless.	Fatty and nutty.
Prune kernels ³ .	35	.9164	.....	-10° C. ⁷	Golden yellow.	Fatty, nutlike.	Bland, nutty, slightly sweet.
Sweet almonds (Spain). ³	49	.9162	.....	-21° C. ⁸	Light yellow..	Nearly odorless, fatty.	Nutlike and fatty.
Bitter almonds (Italy). ³	42.3	.9158	1.4705	-10° C. ⁸	Yellow.....	do.....	Bland and fatty.

¹ By ether extraction.

² Specific gravity and other physical constants represent expressed oil of cherry kernels.

³ Rabak, Frank. Peach, apricot, and prune kernels as by-products of the fruit industry of the United States. U. S. Dept. Agr., Bur. Plant Indus. Bul. 133, p. 15, 1908.

⁴ At 25° C.

⁵ Lewkowitsch, J. Chemical Technology and Analysis of Oils, Fats, and Waxes, v. 2, p. 232. London, 1909.

⁶ At 20° C., see Lewkowitsch, J., op. cit., p. 228.

⁷ Lewkowitsch, J., op. cit., p. 230.

⁸ Lewkowitsch, J., op. cit., p. 235.

⁹ At 25° C., see Lewkowitsch, J., op. cit., p. 236.

An examination of Table I shows that the specific gravity of the refined oil from the pits and of the expressed oil from the kernels corresponds very closely with that of the oils from the other kernels enumerated, thus indicating a like composition of all the oils, since the specific gravity of fixed oils is a property which is influenced largely by its composition. The high specific gravity of the crude pit oil is attributed to the presence of impurities, largely in the form of free fatty acids, which later were removed in the refining process.

The refractive index appears likewise to be affected by the presence of free fatty acids as impurities. The crude oils are seen to possess a lower refractive index than those which have been refined and which therefore contain less impurities. The refractive property of the refined oils corresponds very closely with that of the other oils included in Table I.

The congealing point is a property which is affected by differences in composition. Oils of the same kind, whether crude or refined, often differ in the congealing point, as is shown by the oils from the pits of both the domestic and the imported cherries. The refined cherry oil compares favorably in this respect with the other oils tested.

No marked difference is observed in the color, odor, or taste of the various oils except that the crude oils are slightly darker and have a less agreeable odor and taste than the other oils.

For the purpose of making a further comparison it was deemed advisable to determine the so-called chemical constants (the acid, saponification, and iodine values), which are shown in Table II.

TABLE II.—*Chemical constants of cherry oils compared with various other fruit-kernel oils.*

Source of oil	Free fatty acids.		Saponification value.	Iodine value.	Source of oil.	Free fatty acids.		Saponification value.	Iodine value.
	Acid value.	Calculated as oleic acid.				Acid value.	Calculated as oleic acid.		
Cherry pits (red sour cherries):					Cherry kernels (imported cherries):				
Crude.....	21.5	10.90	189.2	101.7	Peach kernels ²	3.5	1.76	188.5	108.2
Refined.....	15.1	2.58	186.4	102.4	Apricot kernels ²	.83	.41	187	110
Cherry kernels (red sour cherries) cold pressed ² :					Apricot kernels ²	.75	.38	203	107
Cherry pits (imported cherries):					Apricot kernels (same as above, 1 year old).....	13.3	6.68	180	118
Crude.....	6.2	3.13	187.6	106.9	Prune kernels ²	1.9	.95	160	105
Refined.....	22.1	11.10	185.2	110.3	Sweet almonds (market sample) ²	3.5	1.76	193	107.3
	8.4	4.10	189.8	111.4	Bitter almonds ²	1.7	.86	188	106.3

¹ Acid number determined after standing 6 months.

² Kernels obtained from pits about 1 year old.

³ Rabak, Frank. Peach, apricot, and prune kernels as by-products of the fruit industry of the United States. U. S. Dept. Agr., Bur. Plant Indus. Bul. 133, p. 16, 1908.

Before discussing the data in Table II it should be mentioned that the amount of free fatty acids in an oil is wholly dependent upon the age of the oil or of the material from which it is extracted. Freshly expressed or extracted oils from fresh material show but a trace of free acids, often less than 1 per cent. Most fatty oils are unstable as regards the liberation of free fatty acids, the quantity increasing with the age of the oil.

The crude oils from the cherry pits show a high acid content, which, however, was largely reduced in the process of refining. The

cold-pressed oil from the kernels of the domestic cherries, although examined immediately after extraction, contained considerable free acidity. This was doubtless due to the fact that the kernels were taken from pits which had been kept in the laboratory for about a year. As a general rule, oil from old seeds is high in acid content.

The acidity of the oil from the kernels of the imported cherries was considerably lower, due possibly to freshness of the kernels.

With two exceptions, the related oils included in Table II are low in acidity, due to the fresh condition of the oil when examined. Of the two exceptions, one of the oils was a year old before the determination of the free acidity was made, and the other was a market sample, the age of which was not known.

The saponification and iodine values of the cherry oils, which values are a criterion of the composition, agree quite closely with each other and compare favorably with the other oils, only an occasional variation occurring.

From the standpoint of general chemical composition, therefore, the refined oil from the cherry pits and the expressed oil from the kernels are very similar to almond oils and to the oils from peach, apricot, and prune kernels.

CHEMICAL EXAMINATION OF THE FIXED OIL.

The general nature of the fixed oil having been determined, a more detailed analysis was made in order to obtain information bearing on the composition of the oil and to note the effect of refining on the more important properties.

Besides the acid, saponification, and iodine values, the following additional constants were determined, according to the method recommended by the Association of Official Agricultural Chemists:¹

The *volatile acids*, consisting of the glycerids of such acids as butyric, valeric, caproic, etc., were determined and expressed as the Reichert-Meissl number, which is a measure of the volatile acids expressed in cubic centimeters of decinormal alkali required to neutralize the volatile acids contained in 5 grams of oil.²

The *soluble and insoluble acids* were determined, the former representing the percentage of soluble acids calculated as butyric acid and the latter the percentage of insoluble fatty acids (Hehner value).³

The *acetyl value*, which is a measure of the glycerids of hydroxy fatty acids, was determined largely for comparative purposes.⁴

Likewise the *unsaponifiable matter*, which is a variable characteristic, was determined.⁵ The percentage of unsaponifiable matter in a fixed oil is regulated largely by the presence of variable quantities of an alcoholic substance, phytosterol, and other substances, such as coloring matter and waxlike compounds.

¹ Wiley, H. W., ed. Official and provisional methods of analysis, Association of Official Agricultural Chemists. As compiled by the committee on revision of methods. U. S. Dept. Agr., Bur. Chem. Bul. 107 (rev.), 272 p., 13 fig., 1908.

² Wiley, H. W., op. cit., p. 139.

³ Wiley, H. W., op. cit., p. 138, 139.

⁴ Wiley, H. W., op. cit., p. 142.

⁵ Wiley, H. W., op. cit., p. 144.

The insoluble acids comprise the largest portion of all fixed oils, and these were studied in detail by resolving them into the solid and liquid acids of which they are composed. The nature of the solid and liquid acids of an oil is of importance, since upon the percentage of these respective acids depends largely the application of the oil in commerce, whether it can be used for edible purposes, for soap making, or as a drying oil.

The separation of the solid and liquid acids was accomplished by the lead-ether method.¹ The efficacy of this method depends upon the solubility in cold ether of the lead salts of the liquid acids and the insolubility of the same salts of the solid acids. After the separation of the solid and liquid acids the physical and chemical properties of each were determined, from which the approximate composition of the oils was deduced.

The foregoing methods were applied to the crude oil which was extracted from the pits of the domestic cherries by ether; also to the refined oil from the pits and to the expressed oil from the kernels. The results of these determinations are given in Table III.

TABLE III.—*Chemical characteristics of the oils from cherry pits and kernels.*

Source of oil.	Volatile acid, or Reichert-Meissl number.	Soluble acids (calculated as butyric acid).	Insoluble acids.	Acetyl value.	Unsaponifiable.
Cherry pits (red sour cherries):	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>		<i>Per cent.</i>
Crude.....	6.32	1.22	92	20.3	2.45
Refined.....	3.665	.473	92.5	3.45	1.12
Cherry kernels (red sour cherries).....	4.72	.469	92.8	12.67	.44

The data in Table III clearly show the effect of the refining process upon the composition of the oils. The refined oil from the pits more nearly approaches the expressed oil from the kernels. As would be expected, the content of volatile acids is highest in the crude oil from the pits, while the refined oil differs only slightly in this respect from the kernel oil.

The percentage of soluble acids, calculated as butyric acid, decreases much the same as the volatile acids. The crude pit oil shows 1.22 per cent of butyric acid, which in the refined oil is reduced to 0.473 per cent. The refined oil nearly corresponds with the kernel oil.

The insoluble acids, which constitute by far the greatest portion of the oil, show only slight differences in the three oils.

The acetyl values given represent the true values after correction for the volatile acids. If indicated without correction they would be too high by the amount of volatile acids present. Here, also, is

¹ Wiley, H. W., op. cit., p. 142, 145.

seen the favorable effect of the refining process. The acetyl value of 20.3 in the crude pit oil was reduced to 3.45 in the refined oil. The kernel oil, however, shows a considerably higher acetyl value than the refined oil from the pits. This is due to the fact that the kernels were taken from pits which were not in fresh condition.

The amount of unsaponifiable matter in an oil depends largely upon the amount of coloring matter and waxlike substances contained in it. Therefore, the crude oil would be expected to show the highest percentage, which is substantiated by the results obtained.

As previously stated, the insoluble acids are most important factors in determining the quality and usefulness of an oil. Therefore, the physical and chemical constants of these acids were determined, and the results are presented in Table IV. For the purpose of comparison, the known constants of a number of related oils are also included in Table IV.

TABLE IV.—*Physical and chemical constants of insoluble acids of oils from cherry pits and kernels and from other fruit kernels.*

Source of oil.	Color.	Odor.	Taste.	Specific gravity at 25°C.	Refractive index at 25°C.	Congea-ling point.	Neu-trali-zation value.	Iodin value.
Cherry pits:						° C.		
Crude....	Pale brown.	Rancid, fatty.	Bland, fatty, bitter.	0.9019	1.4635	12 to 11	192.4	99.9
Refined..	do.....	Slightly rancid, fatty.	Sweetish, fatty, bitter.	.9137	1.4641	12.5 to 12	179.7	93.7
Cherry kernels.	Pale straw.	Nutlike, slightly rancid.	Sweetish, fatty, slightly bitter.	.9092	1.4635	13.5 to 13	180.8	92.8
Peach kernels. ¹	-----	-----	-----	-----	-----	13.5 to 13	205 to 209.9	94.1 to 101.9
Apricot kernels. ²	-----	-----	-----	.9195	-----	-----	194	99.4 to 103.8
Prune kernels. ³	-----	-----	-----	-----	-----	13 to 12	200.4	95.7 to 102
Almond kernels. ⁴	-----	-----	-----	-----	1.4461	11.8 to 11.3	204	93.5 to 96.5

¹ Lewkowitsch, J. Chemical Technology and Analysis of Oils, Fats, and Waxes, vol. 2, p. 232. London, 1909.

² Specific gravity at 15° C., see Lewkowitsch, J., op. cit., p. 228.

³ Lewkowitsch, J., op. cit., p. 230.

⁴ Refractive index at 60° C., see Lewkowitsch, J., op. cit., p. 237.

Only slight differences in the physical properties—color, odor, and taste—of the insoluble acids are noted in the cherry oils. Data on these points were not available for the other oils. The specific gravity, refractive index, and congealing points of the insoluble acids of cherry oils compare favorably with the same constants of the related oils. The neutralization values differ somewhat from those of the related oils, with the exception of the crude pit oil. This indicates a slightly different composition from the standpoint of fatty acids. The iodine value, which indicates the content of unsaturated acids,

compares favorably with the related oils. General factors, such as the age of the oil and the time intervening between the separation of the insoluble acids and the determination of the constants, would tend to modify the results obtained.

For the purpose of comparison, the physical and chemical characteristics of the solid and liquid acids, after separation from the insoluble acids, were determined, and the results are given in Table V.

TABLE V.—Physical and chemical constants of solid and liquid acids of oils from cherry pits and kernels.

Source of oil.	Solid acids.				Liquid acids.					
	Yield.	Description.	Melting point.	Neu- traliza- tion value.	Yield.	Description.	Spe- cific gravity at 23° C.	Re- fractive index at 25° C.	Neu- traliza- tion value.	Iodin value.
Cherry pits: Crude...	Per cent. 6.27	White, waxy mass, fatty odor.	° C. 51	197.2	Per cent. 84	Golden - yellow liquid, with nutlike odor, and sweet, fatty taste.	0.8917	1.4603	185.1	98
Refined.	8.94	White, waxy mass, with tallow like taste.	49.0	192.3	83.2	Brownish oil, liquid, with nutlike odor, and sweet and bitter after taste.	.9028	1.4643	188.2	108.7
Cherry kernels.	8.96	White, waxy mass, with fatty odor, tallowy taste.	49.5	205.1	82.8	Straw colored, with slightly rancid odor and sweetish bitter taste.	.8941	1.4617	190.6	114

From Table V it will be observed that the solid acids constitute only a small portion of the cherry oils. The crude oil from the pits shows a considerably lower percentage than either the refined oil or the kernel oil. The general physical properties are practically the same. No marked differences are noted in the melting points or in the neutralization value. Judging from the neutralization values it is very probable that the major part of the solid acids consists of stearic acid, which theoretically has a neutralization value of 197.5. The melting point of pure stearic acid is 69° C., but the commercial article is often contaminated with other acids and has been known to melt as low as 56° C. The low melting point of the solid acids in the cherry oils may be attributed to impurities, as the determinations were made without any attempt at purification.

It may safely be assumed, therefore, that the solid acids of cherry oils consist chiefly of stearic acid, with possibly a slight admixture of palmitic acid, which has a neutralization value of 219 and a melting point of 62° C.

The liquid acids comprise the largest portion of the oils. The crude oil from the pits was found to contain 84 per cent, the refined oil 83.2

per cent, and the kernel oil 82.8 per cent. From the physical properties it is very probable that the bulk of the liquid acids consists of oleic acid. The specific gravity of pure oleic acid is reported as 0.895 at 25° C. and the index of refraction at the same temperature as 1.4603. These figures agree very closely with those recorded in Table V. The descriptions of the acids obtained are also very similar to the description of official oleic acid, which is described as yellowish or brownish yellow in color, with a peculiar lardlike odor and taste.

That the bulk of the liquid acids consists of oleic acid is further substantiated by the close agreement of the iodine value of these acids as found in the cherry oils and the iodine value of commercial oleic acid. Although the iodine value of the pure acid is 90, some oleic acids of commerce have values as high as 100 to 110.

The somewhat low neutralization values found in the cherry oils are probably due to slight changes in the fatty acids, as it is well known that these are apt to decompose.

In approximating the composition of cherry oil, only the kernel oil was considered. It was found that this oil consisted of 8.96 per cent of solid acids, which were composed of stearic acid with a possible trace of palmitic acid. Since the glycerid stearin contains 95.73 per cent of stearic acid, it was found by calculation that the oil contained 9.36 per cent of stearin. The original oil consisted of 82.8 per cent of liquid acids, which, calculated as oleic acid and reduced to terms of olein (olein contains 95.7 per cent oleic acid), corresponds to 86.5 per cent of the glycerid olein.

A brief summary of the results obtained by the chemical examination indicates, therefore, the following approximate composition of cherry kernel oil: Olein, 86.5 per cent; stearin, including a possible trace of palmitin, 9.36 per cent; the remaining portion of the oil consists of smaller amounts of free acids, volatile acids, and unsaponifiable matter.

REACTION OF THE OIL TOWARD REAGENTS.

Color reactions are frequently applied to fixed oils, although perhaps more for the purpose of detecting adulterations than for determining the quality. Certain reagents produce characteristic color reactions; therefore, when it is desired to compare related oils it is often expedient to ascertain the behavior of the oils toward reagents. Since this investigation deals with an oil which is closely related to several well-known commercial oils, a number of color reactions were therefore determined and comparison was made with the color reactions obtained from the affiliated oils extracted by means of ether in this laboratory. The results are presented in Table VI.

TABLE VI.—Color reactions of oils from cherry pits and kernels and of other related oils.

Source of oil.	Original color.	Nitric acid.	Nitric acid, fuming.	Bieber's test (equal parts fuming nitric acid, sulphuric acid, and water).	Phloroglucin test (0.1 percent phloroglucin in ether applied in presence of nitric acid).	Sulphuric acid (75 per cent).	Thaïdm test (fuming nitric acid and water, equal parts).
Cherry pits:							
Crude.....	Golden yellow.....	Pale brown to dirty gray-brown.	Deep red-brown to dark brown.	Dirty yellowish with no suggestion of pink.	Reddish.....	Brown, dark brown.	Deep, yellow solid mass with yellow liquid.
Refined.....	Deep straw.....	Reddish brown to dirty red.	Deep red to dark brownish red.	Dirty yellowish with pink tinge.	Brownish with red tinge.	Brownish red to brown.	Deep yellow viscous mixture, colorless liquid.
Cherry kernels:							
Cold pressed....	Pale straw.....	Pale pink to dirty lavender.	Deep red to brownish red.	Very pale pink coloration.	Yellowish brown.....	Pale brownish red to greenish brown.	Solid pale yellow mixture, nearly colorless liquid.
Imported cherries.	Deep straw.....	Pale brownish.....	Dark brownish red to dark brown.	Dark dirty yellowish.	Pale brownish with reddish border.	Brown to brownish red.	Pale yellow, nearly solid mixture with yellow liquid.
Bitter almonds....	Pale yellow.....	Very faintly pink to dirty pink.	Light brownish red to brown.	Yellowish, somewhat darker than original.	Very pale pink.....	Flesh.....	Straw-colored solid with nearly colorless liquid.
Sweet almonds....	Pale straw.....	do.....	Pale brownish red to brownish.	do.....	Pale crimson.....	Pale flesh.....	Do.
Peach kernels.....	Very faint straw....	Pink to deep dirty lavender.	Reddish to red-brown.	Decided pink.....	Dark yellow with pinkish tinge.	Deep pink.....	Dark yellowish solid with nearly colorless liquid.
Apicot kernels....	Pale yellow.....	Pink to dirty lavender.	Light brownish red to pale brown.	Very pale pink.....	do.....	Light pink.....	Pale yellow solid with colorless liquid.
Prune kernels.....	Deep straw.....	Deep pink to pale lavender.	Pale brownish red to pale brown.	Pale pink.....	Deep crimson.....	Straw.....	Pale yellow solid with yellowish liquid.

The color reactions obtained by the use of the various reagents show some differences, yet they bear a certain fixed relationship, differing usually only in intensity. From the color reactions produced it can not be stated that the quality of one oil is superior to that of any other, but a close relationship is clearly obvious. The test with fuming nitric acid and water, as prescribed in the United States Pharmacopœia¹ for the expressed almond oil, depends upon the formation of a polymerized solid compound with the olein of the oil. This test emphasized most strongly the similarity of cherry-kernel oil to official almond oil and also to the other related oils.

Inasmuch as almond kernels and peach and apricot kernels yield fixed oils of commercial value, attention is called to the close resemblance of cherry oil to these oils. Careful inspection of the chemical and physical properties has shown that, although it is not identical with either almond, peach, or apricot oil, it is not fundamentally different from any of these. The variations observed may not be due wholly to difference in composition, since often fixed oils from the same source possess varying properties. The condition of the material from which the oil is extracted and also the seasonal factors are influential in affecting the ultimate quality of an oil.

Because of this close relationship, cherry-kernel oil should therefore be adapted to the same uses for which the other oils are employed.

AVAILABLE QUANTITY OF THE FIXED OIL.

Of first importance in connection with the possible commercial utilization of waste cherry pits is the available quantity of the material. A conservative estimate of a normal year's output from the red sour cherries is 1,600 tons. By actual experiment it was found that 28 per cent of the pits consists of kernels. On this basis there would be available annually 448 tons of kernels. By the use of modern hydraulic presses this quantity of kernels should yield 134 tons of fixed oil, or 268,000 pounds. In addition to this, there is also an annual accumulation of about 650 tons of pits from the imported cherries. Only 9 per cent of these pits was found to consist of kernels. The quantity of kernels available from this source, therefore, would be 58.5 tons. On extraction with ether these kernels yielded 50 per cent of oil. Subjected to hydraulic pressure about 45 per cent would be obtainable, which would give approximately 26 tons, or 52,000 pounds of oil. Therefore, the total quantity of fixed oil available from the annual accumulation of cherry pits, both domestic and imported, would be 160 tons, or 320,000 pounds.

¹ The Pharmacopœia of the United States . . . Eighth decennial revision, p. 307. Philadelphia, 1907.

USES OF THE FIXED OIL.

Cherry oil should be adapted to all purposes for which almond, peach, or apricot oil is used. Almond oil is used chiefly in pharmaceutical preparations, and the demand is considerable. Therapeutically, peach and apricot oils are as efficient as almond oil. Peach and apricot oils have recently been manufactured in California for use as edible oils and are said to excel olive oil in flavor and taste.

VALUE OF THE FIXED OIL.

The value of cherry oil would naturally depend upon its use and the demand for oils of this character. The importation of sweet and bitter almond oil for the year ended June 30, 1914, was 38,586 pounds, valued at \$36,620.¹ The price of peach-kernel oil has ranged from 22 cents a pound in 1913 to 45 cents in 1915. No data are available regarding the extent of the importation of this oil or of apricot oil, although it is known that large quantities are imported annually.

VOLATILE OIL.

METHOD OF EXTRACTION.

The volatile oil does not exist as such in the kernels, but is the result of glucosidal hydrolysis, the glucosid amygdalin reacting with the ferment emulsin in the presence of water. It is one of the comparatively few oils which are obtained only after chemical reaction has taken place.

The first step necessary in extracting the volatile oil from the kernels was to produce the reaction between the glucosid amygdalin and the ferment emulsin under conditions which would insure a complete formation of the oil. This was best accomplished by the method formulated in a previous investigation,² which in substance is as follows: To one part of the ground kernels or press cake add two or three parts of lukewarm water, and macerate with frequent agitation for about one hour, after which pass steam, under slight pressure, into the mixture and distill until approximately four parts of distillate are obtained. The volatile oil, which is heavier than water, will separate on the bottom of the receiving vessel. The upper aqueous distillate, which is saturated with the oil in solution, can be drawn off and subjected to distillation by the direct application of heat. This process can be continued until the full yield of oil is obtained.

¹ U. S. Department of Commerce. Foreign Commerce and Navigation of the United States for the Year Ending June 30, 1914, pp. 820-821. Washington, 1915.

² Rabak, Frank. Peach, apricot, and prune kernels as by-products of the fruit industry of the United States. U. S. Dept. Agr., Bur. Plant Indus. Bul. 133, p. 24, 1908.

In order to obtain the maximum yield it is very important that the maceration of the ground material be made with lukewarm water, as the reaction between the constituents, with the formation of oil, takes place most expeditiously at that temperature. It is also necessary to conduct the maceration in a closed vessel, preferably in the still itself, in order to avoid the loss of oil by evaporation.

As a preliminary experiment, a quantity of ground pits was treated according to this method and distilled in a still consisting essentially of a still body and a condenser. Live steam was passed into the macerated mixture, and the distillate collected in a receiving vessel of glass, from which the aqueous distillate was easily decanted. The oil accumulated on the bottom, and the final separation was made by means of a separatory funnel. After cohobation of the distillate, which consists in redistilling by direct application of heat, the yield of oil was found to be 0.1 per cent.

By careful manipulation a yield of 0.95 per cent of volatile oil was obtained from the press cake which remained after the extraction of the fixed oil from the kernels. This is equivalent to nearly 1 pound of oil from every 100 pounds of press cake.

It is recommended that the volatile oil be extracted from the kernels rather than from the pits direct, both from an economical standpoint and from the ease of manipulation, since much loss is avoided in working with the smaller volume of material in the form of the press cake than with the much larger bulk of ground pits.

PHYSICAL AND CHEMICAL PROPERTIES OF THE VOLATILE OIL.

The physical and chemical properties of the volatile oil were determined and together with the yields were tabulated with other kernel oils, which included several market samples of bitter-almond oil. According to the United States Pharmacopœia, bitter-almond oil is designated as being derived from bitter almonds and "other seeds containing amygdalin."¹ Cherry kernels contain amygdalin, and cherry oil should therefore belong to the same class as bitter-almond oil.

The data obtained from the physical and chemical examination of the volatile oils are presented in Table VII.

An examination of Table VII shows that the yield of cherry oil was somewhat less than that of the other oils. This is explained by the fact that the kernels used in the experiment were from pits which had been in the laboratory for a considerable length of time and had undoubtedly deteriorated. The yield of oil from fresh kernels would very probably be higher. However, the yield obtained was sufficient to justify the use of cherry kernels for the production of oil.

¹ The Pharmacopœia of the United States . . . Eighth decennial revision, p. 306. Philadelphia, 1907.

TABLE VII.—*Yield, physical properties, and chemical composition of the volatile oils from various fruit sources.*

Source of oil.	Yield from press cake.	Color.	Odor.	Taste.	Specific gravity at 24 C.	H Cn. ¹	Benzaldehyde. ²
Cherry kernels.....	<i>Per cent.</i> 0.95	Pale straw..	Pleasant, strong, bitter-almond-like.	Sweet and very pungent.	1.050	<i>Per ct.</i> 4.21	<i>Per ct.</i> ³ 81.53
Cherry pits.....	.10	Golden yellow.	Agreeable characteristic.	Sweet, strong, pungent.	1.012	7.94	67.95
Peach kernels ⁴	1.17	Pale straw..	Bitter-almond-like, somewhat irritating.	Sweet and pungent.	1.068	2.20	73.1
Apricot kernels ⁴	1.33	Straw.....	Aromatic, almond-like.	Sweet and intensely pungent.	1.080	2.05	³ 88.7
Prune kernels ⁴	.71	Faint straw.	Strong benzaldehyde.	Sweet and pungent.	1.050	1.75	76
Bitter almonds ⁴	1.15	do.....	Less aromatic (fainter than above).	Sweet, less pungent.	1.056	4.80	62
Bitter-almond oil (market sample 2 years old).	.....	Golden.....	Characteristic, mellow.	Very pungent.	1.059	2.57	78.45
Bitter-almond oil (market sample 1 year old).	.....	Pale yellow.	Strong and penetrating.	Sweetish pungent.	1.058	2.12	80.6
Benzaldehyde (several years old).	.....	Deep yellow.	do.....	Very sweet, pungent.	1.062	⁵ 13.7	77.5

¹ Assayed according to the volumetric method of the Pharmacopœia of the United States, Eighth decennial revision, p. 306. Philadelphia, 1907.

² Assayed by the sodium bisulphite method. The Pharmacopœia. Loc. cit.

³ Assayed immediately after distillation.

⁴ Rabak, Frank. Peach, apricot, and prune kernels as by-products of the fruit industry of the United States. U. S. Dept. Agr., Bur. Plant Indus. Bul. 133, p. 23, 25, 1908.

⁵ Benzoic acid.

The physical properties do not differ greatly; in fact, they nearly coincide with those of the other oils. In hydrocyanic-acid content the cherry oil was found to be somewhat higher than in the other oils, but it was nearly within the limits of the Pharmacopœia, which requires not less than 2 nor more than 4 per cent. The benzaldehyde content, which, because of its instability under ordinary means of preservation fluctuates noticeably in this class of oils, compares favorably with the other kernel oils. The pharmacopœial requirement with regard to benzaldehyde content is that it shall not be less than 85 per cent. The benzaldehyde content of the cherry oil, although lower than the requirement, is not as low as in the two samples of bitter-almond oil purchased in the open market, both of which were slightly deficient on account of deterioration, which was undoubtedly due to the age of the oils. This deterioration in benzaldehyde content is more or less rapid, because of the ease with which it oxidizes to benzoic acid. The sample of benzaldehyde examined illustrates the change which takes place under ordinary conditions. The sample, which originally was a pure compound, after standing for several years shows but 77.5 per cent of benzaldehyde. The free acidity, calculated as benzoic acid, was 13.7 per cent. The benzaldehyde content bears a direct relationship to the specific gravity; the higher the benzaldehyde content the lower the specific gravity.

On the whole, the properties of cherry oil compare very favorably with the commercial oils, considering the many unfavorable factors which unavoidably enter into the distillation on a laboratory scale, and it may therefore be considered that for all practical purposes this oil is equal to the oil of bitter almonds and the other kernel oils.

AVAILABLE QUANTITY OF THE VOLATILE OIL.

Approximating the total available quantity of kernels from the domestic cherries at 448 tons and deducting 30 per cent, the quantity of fixed oil capable of being extracted, there would remain about 314 tons of press cake. It has been shown that 0.95 per cent of volatile oil can be obtained from the press cake, and there would result, therefore, practically 3 tons of volatile oil, or 6,000 pounds.

USES OF THE VOLATILE OIL.

Bitter-almond oil, aside from its use for medicinal purposes, finds a widespread use in the manufacture of perfumery and confectionery. In the perfumery trade the demand is for the genuine oil rather than for the synthetic article, as the odoriferous properties are much finer and more agreeable. The importation of bitter-almond oil for the year ended June 30, 1914, reached a total of 7,525 pounds, valued at \$21,954,¹ showing that the demand for this oil is keen. For some time prior to August, 1914, the price of bitter-almond oil has shown a gradual increase, the wholesale market quotations ranging from \$3.25 to \$4.75 in 1910² to \$3.50 to \$6.50 during the first six months of 1914.² Since then the price has risen rapidly, due apparently to lack of importations. At the present time (January, 1916) the oil is quoted at \$9.25 to \$11 a pound.³

VALUE OF THE VOLATILE OIL.

Assuming that 6,000 pounds of volatile oil can be produced annually, the gross income from the total available output of kernels, calculated at the minimum price quoted at the present time, would be \$46,500. Therefore it would seem reasonable to suppose that the production of volatile oil from waste cherry pits should meet with favorable attention as a means of converting the now useless waste into a source of profit.

CHERRY-KERNEL MEAL.

CHEMICAL CONSTITUENTS.

After distilling the volatile oil from the press cake, the residue which remained consisted of a mushy mass. The moisture was re-

¹ U. S. Department of Commerce. Foreign Commerce and Navigation of the United States for the Year Ending June 30, 1914, p. 821. Washington, 1915.

² Oil, Paint, and Drug Reporter.

³ Oil, Paint, and Drug Reporter, v. 89, no. 3, p. 40. 1916.

moved from this mass partly by pressure and partly by drying, after which the dried mass was ground to a meal. Upon examination, the meal was found to contain 1.06 per cent of moisture; 3.94 per cent of ash; 13.1 per cent of ether extract; 30.87 per cent of protein; 8.9 per cent of crude fiber, and 42.13 per cent of nitrogen-free extract.

In order to interpret these results with regard to the value of the meal as a stock food, in which it probably would find its chief use, comparison of the various constituents was made with those of several feeding stuffs as recorded by Henry.¹ The comparison is shown in Table VIII.

TABLE VIII.—*Cherry-kernel meal compared with various commercial feeding stuffs.*

Feeding stuff.	Constituents (per cent).					
	Moisture.	Ash.	Protein.	Nitrogen-free extract.	Fiber.	Ether extract.
Cherry-kernel meal.....	1.06	3.94	30.87	42.13	8.9	13.1
Soy-bean cake.....	11.3	5.9	42.7	28.1	6.0	6.0
Linseed meal.....	9.8	5.5	33.9	35.7	7.3	7.8
Cottonseed meal.....	7.0	6.6	45.3	24.6	6.3	10.2
Coconut cake.....	10.3	5.9	19.7	38.7	14.4	11.0
Palm-nut cake.....	10.4	4.3	16.8	35.0	24.0	9.5
Sunflower-seed cake.....	10.8	6.7	32.8	27.1	13.5	9.1
Peanut cake.....	10.7	4.9	47.6	23.7	5.1	8.0
Rape-seed cake.....	10.0	7.9	31.2	30.0	11.3	9.6
Sesame-oil cake.....	7.4	8.8	36.7	17.3	3.8	26.0
Corn meal.....	15.0	1.4	9.2	68.7	1.9	3.8

The low percentage of moisture in the cherry-kernel meal is due to the fact that the material was dried just before the determination was made. The percentage of ash is somewhat lower than in any of the other feed cakes, with the exception of corn.

From the standpoint of food value the most important constituents are the ether extract, consisting largely of fat and other soluble constituents; the protein, consisting of nitrogen compounds; and the nitrogen-free extract, which includes soluble carbohydrates, such as sugar, starch, gums, etc. The meal is considerably richer in ether extract than any of the foods enumerated, with the exception of sesame-oil cake. In content of nitrogen-free extract it excels nearly all. The protein content, also, compares very favorably with the more important feeding stuffs of commerce. The percentage here given is doubtless below the actual percentage of soluble carbohydrates, due to the partial extraction of the water-soluble compounds of the meal by the water contained in the still after distillation. To illustrate: It was found that the water extract from the distillation of a quantity of ground pits, after evaporation to dryness, constituted 6.7 per cent of the original ground material. The solid extract after powdering was chocolate brown in color, with a rather pleasant

¹ Henry, W. A. *Feeds and Feeding* . . . ed. 10, p. 566-567. Madison, Wis., 1910.

taste suggesting roasted grain. This extract was readily soluble in water. The protein content was found to be 33.93 per cent. The utilization of this waste water-soluble extract by evaporation with the meal left in the still would add much to the nourishing properties of the meal. The fiber content, although not high in comparison with some of the other meals, was augmented by the presence in the kernels, before grinding, of particles of the pits which escaped separation in the cracking process.

AVAILABLE QUANTITY, USES, AND VALUE OF CHERRY-KERNEL MEAL.

Roughly estimated, the total available quantity of meal which would result after extracting the oil would be about 300 tons from the domestic cherries and 30 tons from the imported cherries.

The utility of the meal, as shown by its composition, should be similar to that of the general class of oil cakes now sold on the market for stock foods.

Regarding the commercial value only an estimate can be made. Based on the current prices of linseed meal, which is about \$39 per ton, the estimated money value of the yearly output of cherry-kernel meal would be about \$12,870.

COMMERCIAL PRODUCTS OBTAINABLE FROM CHERRY JUICE.

Attention has already been called to the large quantity of juice which accumulates during the operation of pitting cherries. The juice is bright red in color, with the odor and taste of cherries. Using the sugar and acid content as a basis for investigation, several experiments were conducted, with a view to preparing products which might be of commercial value.

ALCOHOL FROM CHERRY JUICE.

In order to convert the cherry juice into alcohol, a cake of compressed yeast was added to 1 kilo of filtered juice and the mixture kept at 30° C. for a period of 24 hours, with occasional agitation. After this period, fermentation had completely ceased. The mixture was then filtered, neutralized with milk of lime, and distilled. A small quantity of phosphoric acid was added to the distillate and a second distillation made. The alcohol obtained was deodorized by the addition of potassium permanganate and again distilled. By this method it was calculated that 4.36 per cent of absolute alcohol, or 4.6 U. S. P. alcohol (95 per cent by volume), could be prepared from the waste juice.

SIRUP FROM CHERRY JUICE.

For the preparation of sirup, a quantity of the filtered juice was evaporated in vacuo after previously neutralizing the acidity with milk of lime. The calcium salts of the acids were filtered from the

hot sirup by means of vacuum filtration. This procedure was carried on twice during the concentration of the juice. The yield of sirup obtained was about 20 per cent. The calcium salts (probably consisting largely of calcium malate) after drying resulted to the extent of 1.35 per cent. The sirup obtained was dark brown in color, with a pleasant, sweet, slightly tart taste.

The specific gravity at 24° C. was 1.34. Assayed gravimetrically by means of Fehling's solution the content of reducing sugars was found to be 43 per cent and the total sugars 52.1 per cent.

The free acidity was determined by titration with N/10 potassium hydroxid V. S. and calculated as malic acid by means of the malic-acid factor (1 c. c. N/10 KOH=0.0067 gm. malic acid). The sirup was found to contain 1.3 per cent of malic acid.

These properties of the sirup are most variable and are subject to fluctuation, depending to a great extent upon the consistency to which the sirup is evaporated. The greater the concentration the higher the percentage of the important constituents.

JELLY FROM CHERRY JUICE

For the preparation of jelly the cherry juice was concentrated with cane sugar (1 pound of sugar to 1,200 c. c. of juice) in a vacuum to a sirupy consistency. Purified gelatin was then added (one-half ounce of gelatin dissolved in one-half pint of water) and the mixture set aside in a cool place. The resulting jelly was wine red in color, with a fruity odor and a very pleasant tart taste.

Although this process is a very crude one, it shows the possibility of converting the juice into a product which is decidedly wholesome. Other processes of preparing jelly from juices of this nature by the use of pectin or parings from fruits which are rich in pectin would doubtless be productive of even more promising results.

Calculated with the amount of sugar added it was found that about 81.6 per cent of jelly could be prepared from the juice.

AVAILABLE QUANTITY, USES, AND VALUE OF THE ALCOHOL, SIRUP, AND JELLY FROM CHERRY JUICE.

The prospect of profitably converting the juice into commercially useful products would depend largely upon the available quantity. As previously stated, approximately 105,000 gallons of juice result from the pitting process. The alcohol production from this quantity of juice would be about 5,000 gallons. The usefulness and commercial value of alcohol is well known and needs no further comment.

The quantity of sirup capable of being manufactured from the total available juice, calculating the yield of sirup as 20 per cent, would be 21,000 gallons. The usefulness of the sirup as a household commodity can hardly be questioned. It is also possible that it could

be reapplied to the canning of cherries, much as the sirup from pineapple waste is at present utilized. The value must necessarily be determined by the uses to which it can be put and the demand created thereby. Its pleasant taste and agreeable flavor should create a demand for the product as a table commodity.

The total quantity of jelly which could be manufactured from the juice available annually would approximate 85,680 gallons. The actual value of this quantity of jelly can not be accurately estimated, but it can safely be assumed that a considerable margin of profit would result after deducting the expense of manufacture.

SUMMARY.

To briefly recapitulate the results of the foregoing investigation, it is shown that the waste products from the cherry industry can be reduced to a number of valuable products:

(1) The fixed oil, which is perhaps the most important product, is, in its properties and general characteristics, so closely related to the commercial oil of almonds that it is placed in an important position with respect to usefulness and value. The oil expressed from the fresh kernels is quite similar to almond oil and its use as an article of commerce, applied along pharmaceutical and therapeutical lines, or as a condimental oil, or even for soap-making purposes, should be assured.

(2) The volatile oil which can be produced from the press cake after the fixed oil has been extracted is practically identical with the oil of bitter almonds, thus rendering its usefulness the same in every way as that of bitter-almond oil.

(3) The meal, which is the final residue, has been shown to possess nourishing properties, much the same as those of the more common feeding stuffs on the market.

(4) The juice has been shown to be capable of being transformed into alcohol, sirup, or jelly, and it is reasonable to assume that there should be a demand for such products.

The success of an undertaking involving the by-products in question would depend largely upon the efficacy of any proposed system whereby the products could be manufactured. Since the waste as it accumulates is not confined to any particular section, perhaps the most feasible method would be to accumulate the waste at some central point. The most convenient plan then would be to conduct the manufacture on a cooperative basis, much as the present system of cooperative creameries is conducted, whereby the cream produced in any dairy section is conducted to a central plant where the products are manufactured.

While the object of this investigation is principally to point out the possibilities existing in the cherry by-products, it is hoped that the information contained herein will serve as an incentive to the proper disposition of these waste products, with their ultimate reduction into products of commercial utility and value.

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HENRY W. HENSHAW, Chief

Washington, D. C.

PROFESSIONAL PAPER

March 24, 1916

BIRDS OF PORTO RICO

By

ALEX WETMORE, Assistant Biologist

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February 19, 1916

THE SPRUCE AND BALSAM FIR TREES OF THE ROCKY MOUNTAIN REGION

By

GEORGE B. SUDWORTH, Dendrologist

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L. O. HOWARD, Chief

Washington, D. C.

PROFESSIONAL PAPER

March 6, 1916

NOTES ON FIVE NORTH AMERICAN BUFFALO
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By

ARTHUR W. JOBBINS-POMEROY, Entomological Assistant

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and the Bureau of Chemistry, CARL L. ALSBERG, Chief

Washington, D. C.



January 8, 1916

THE MILLING OF RICE AND ITS
MECHANICAL AND CHEMICAL EFFECT
UPON THE GRAIN

By

F. B. WISE, Assistant, Office of Grain Standardization, and
A. W. BROOMELL, Assistant Chemist, Food-
Control Laboratory

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L. O. HOWARD, Chief

Washington, D. C. PROFESSIONAL PAPER February 16, 1916

TERMITES, OR "WHITE ANTS,"
IN THE UNITED STATES: THEIR DAMAGE,
AND METHODS OF PREVENTION

By

THOMAS E. SNYDER, M. F., Assistant in Forest Entomology,
Forest Insect Investigations

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UNITED STATES DEPARTMENT OF AGRICULTURE
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WM. A. TAYLOR, Chief

Washington, D. C. PROFESSIONAL PAPER December 28, 1915

DIRECTIONS FOR BLUEBERRY
CULTURE, 1916

By

FREDERICK V. COVILLE, Botanist

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Contribution from the Bureau of Plant Industry
WM. A. TAYLOR, Chief

Washington, D. C.



February 10, 1916

CEREAL EXPERIMENTS IN MARYLAND
AND VIRGINIA

By

T. R. STANTON, Scientific Assistant, Office of
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LOGAN WALLER PAGE, Director

Washington, D. C.

PROFESSIONAL PAPER

April 21, 1916

EXPERIMENTS ON THE ECONOMICAL
USE OF IRRIGATION WATER
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By

DON H. BARK, Irrigation Engineer, Division of
Irrigation Investigations

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OFFICE OF THE SECRETARY
Contribution from Office of Farm Management, W. J. Spillman, Chief

Washington, D. C.

PROFESSIONAL PAPER

January 17, 1916

**FARM MANAGEMENT PRACTICE OF
CHESTER COUNTY, PA.**

By

W. J. SPILLMAN, Chief, Office of Farm Management
H. M. DIXON, Assistant Agriculturist
G. A. BILLINGS, Agriculturist

This study is based on the operations of 643 farms in an old and prosperous agricultural section. It is designed to develop fundamental and broadly applicable principles of good farm management



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HENRY S. GRAVES, Forester

Washington, D. C. PROFESSIONAL PAPER April 26, 1916

GROUND-WOOD PULP

- Part I—THE GRINDING OF COOKED AND UNCOOKED
SPRUCE
Part II—SUBSTITUTES FOR SPRUCE IN THE MANUFAC-
TURE OF GROUND-WOOD PULP

By

J. H. THICKENS, Chemical Engineer in Forest Products, and
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Contribution from Office of Public Roads and Rural Engineering
LOGAN WALLER PAGE, Director

Washington, D. C.

PROFESSIONAL PAPER

March 17, 1916

METHODS FOR THE DETERMINATION
OF THE PHYSICAL PROPERTIES
OF ROAD-BUILDING ROCK

By

FRANK H. JACKSON, Jr., Assistant Testing Engineer

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UNITED STATES DEPARTMENT OF AGRICULTURE
BULLETIN No. 348

Contribution from the Office of Public Roads and Rural Engineering
LOGAN WALLER PAGE, Director

Washington, D. C. PROFESSIONAL PAPER April 4, 1916

RELATION OF MINERAL COMPOSITION AND
ROCK STRUCTURE TO THE PHYSICAL
PROPERTIES OF ROAD MATERIALS

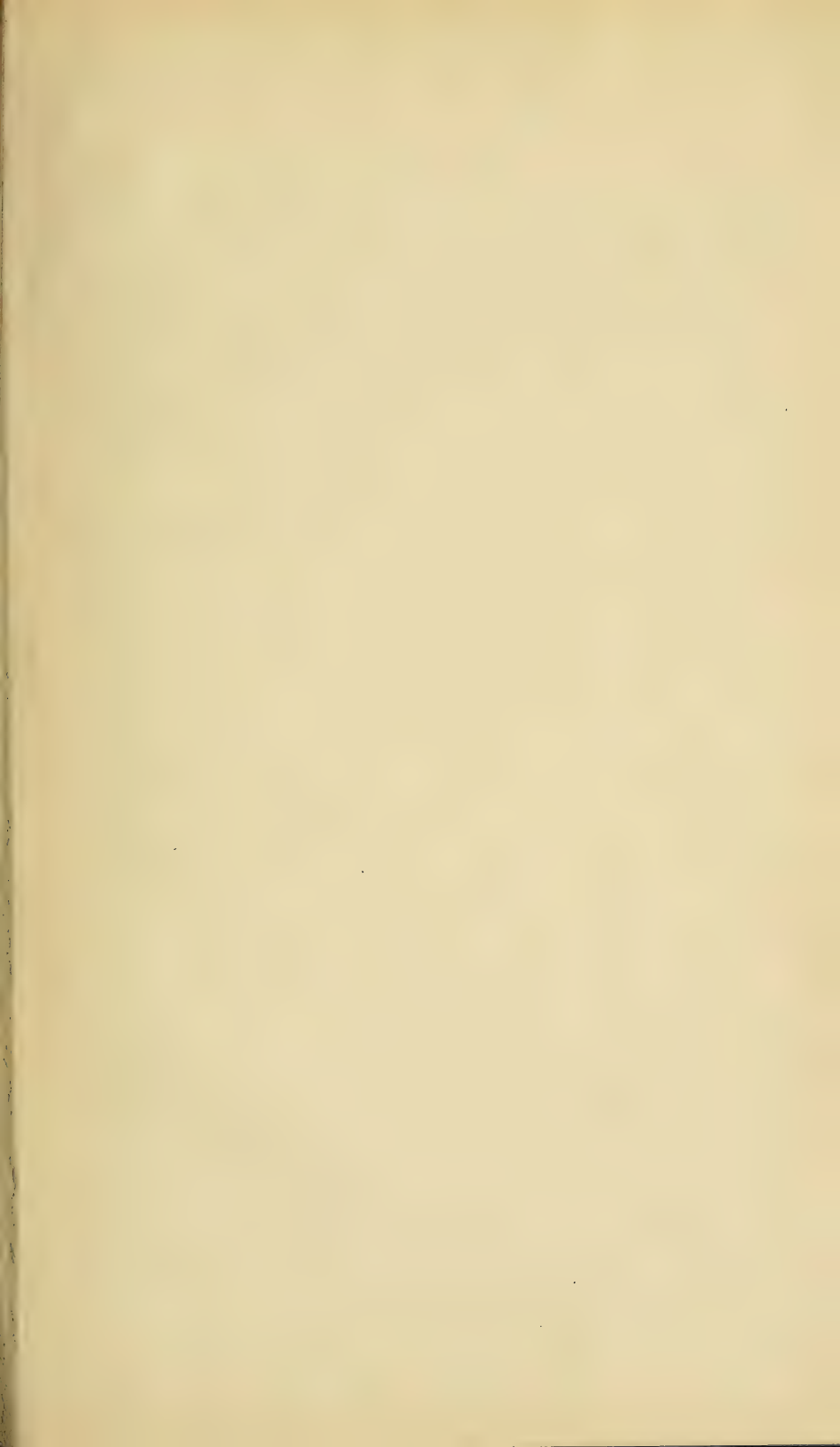
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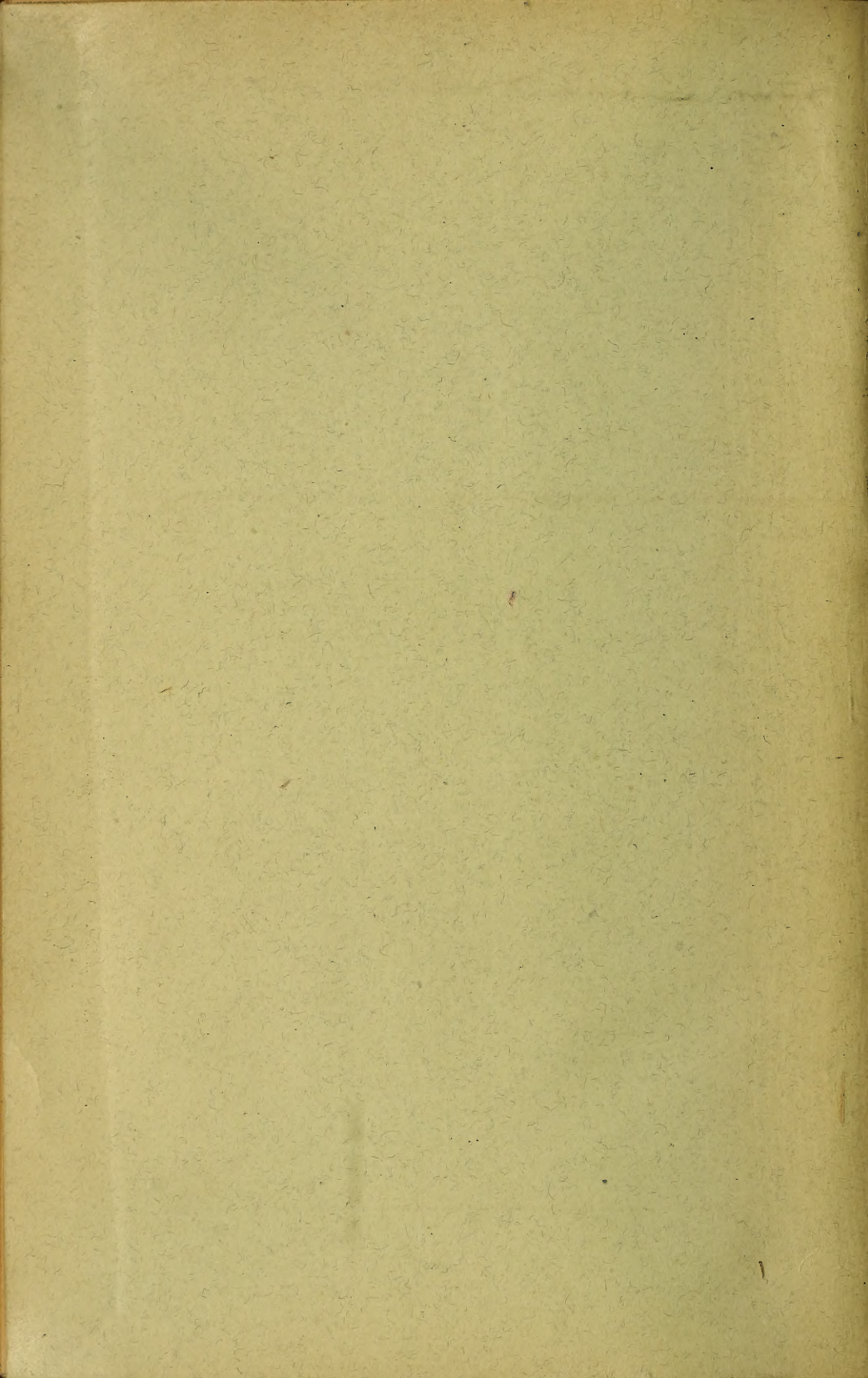
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